Tampere University

PAVEL CHISTOV

# INTEGRATION OF BUS TRAVEL EXPERIENCE TOOLKIT AND SENSOR DATA VISUALIZATIONS INTO LIVING LAB BUS PLATFORM

Faculty of Information Technology and Communication Sciences (ITC)
Master of Science thesis
May 2019

# ABSTRACT

PAVEL CHISTOV: Integration of Bus Travel Experience Toolkit and sensor data visualizations into Living Lab Bus platform
Master of Science thesis
Tampere University
Master's Degree Programme in Information Technology
Supervisors: Professor Kaisa Väänänen, Doctoral Student Elina Hildén
May 2019

Public bus transportation has always had a significant impact on citizens' well-being. Vast number of initiatives to improve services and overall travel experience is proposed by transportation companies. Thus, there is a significance of providing open design and inspiration tools that would enable software developers to ideate and create new solutions in the field. This would allow interested citizens to directly contribute to the improvement and development of the public bus transportation by developing new services in a publicly available development platform.

Living Lab Bus (LLB) Is a project funded by Business Finland and various partners and coordinated by VTT Technical Research Centre. LLB presents an opportunity to service ideation and design by providing a fleet of sensor-supplemented buses, development platform with an access to the sensor data (Developer Portal) and ideation tools. Bus Travel Experience toolkit contains Context Cards, Travel Experience Model, Passenger Personas and Passenger Journey Map. This toolkit is meant to aid developers in design and development of mobile applications using LLB. Platform also offers access to an application hub "Oma kokoelma" ("Own collection") that allows developers to publish their applications and receive feedback on their work from real users.

This thesis work explored the ways of integrating Toolkit and sensor data visualization into LLLB platform. The study consists of two developer studies and two design and implementation phases. The first developer study revolved around properties of the Toolkit and potential data visualizations and developers' perception of them. The method used was based on conducting scenario evaluation sessions where developer would give an opinion on potential use cases of the Toolkit and sensor data. During the second practical phase a prototype of future Toolkit portal was developed and then tested with software developers during third phase. In a final fourth phase, prototype was reworked based on the feedback from previous phase.

The result of this design research is a fully functioning production-ready build of the web portal that contains both Toolkit and sensor data visualizations. This portal also incorporated some of the adjustments to the Toolkit that would help developers to successfully utilize it in their efforts.

Additionally, the thesis presents findings regarding developers' ideation process and impact on the usage of the toolkit: *importance of research background of the tools*, *significance of familiar terminology* and *presentation and format of the tools*.

Keywords: public bus transportation, data visualization, developer experience, ideation, inspiration.

# PREFACE

My own interest in solving complex design problems was a major driver for this year long work. A year long journey led to that moment when I can say that I am truly proud of the work I've done. I believe I grew as a specialist and simply as a person after all these months.

Every single day of that journey I was grateful for a provided opportunity to work on such complex and unique combination of topics of bus transportation, data visualization and developer's experience. Thus, I would like to give many thanks to Professor Kaisa Väänänen for supervision of this thesis work and guidance that you have given me along the way. Thank you for recognizing my potential and giving me a shot at Living Lab Bus project.

I also want to thank Aparajita Chowdhury and former colleagues at IHTE and LLB project for their support and feedback. I would also like to express my endless gratitude to Elina Hildén and her willingness to help at any given moment. I also want to show gratitude to all the teachers and mentors that gave me necessary knowledge throughout the past 3 years at Tampere University.

And I immensely grateful for support and positive energy my family gave me and for being there for me.

Tampere, 02.05.2019

Pavel Chistov

# CONTENTS

1. INTRODUCTION ..... 1
1.1. Motivation and background of the research ..... 1
1.2. Goals and the scope of the research ..... 2
1.3. Structure of the thesis ..... 3
2. THEORETICAL BACKGROUND ..... 4
2.1. Ideation and inspiration ..... 4
2.1.1. Ideation methods, techniques and tools ..... 6
2.1.2. Ideation platforms ..... 10
2.2. Bus Travel and Passenger Experiences ..... 12
2.3. Data visualization ..... 14
2.3.1. Data visualization principles and examples ..... 14
2.3.2. Bus data visualizations ..... 16
2.4. Developer experience ..... 18
2.5. Summary ..... 21
3. PRACTICAL BACKGROUND ..... 22
3.1. Living Lab Bus – Developer Portal ..... 22
3.2. Bus Travel Experience Toolkit ..... 24
4. RESEARCH PROCESS ..... 27
4.1. Research schedule ..... 27
4.2. Research methods ..... 28
4.2.1. Qualitative methods of data gathering ..... 28
4.2.2. Quantitative methods of data gathering ..... 29
4.2.3. Methods of analysis ..... 30
5. DEVELOPER STUDY – SCENARIO EVALUATION ..... 31
5.1. Participants ..... 31
5.3. Procedure and materials ..... 32
5.3.1. “Inexperienced developer” scenario and wireframes ..... 33

5.3.2. “Limited designer” scenario and wireframes ..... 38
5.4. Findings ..... 41
6. PROTOTYPE DESIGN AND IMPLEMENTATION ..... 47
6.1. Goals and user tasks ..... 47
6.2. Implementation tools ..... 48
6.3. Design approach ..... 49
6.3.1. General theme and layout ..... 49
6.3.2. Navigation and flow ..... 50
7. DEVELOPER STUDY - PROTOTYPE TESTING ..... 62
7.1. Participants ..... 62
7.2. Procedure and materials ..... 62
7.3. Completion rates ..... 64
7.4. Questionnaire results ..... 65
7.5. Interview findings ..... 68
8. PROTOTYPE REWORK ..... 72
8.1. Prototype changes ..... 72
9. DISCUSSION AND CONCLUSION ..... 81
9.1. Summary of Findings ..... 81
9.2. Discussion ..... 82
9.3. Limitations ..... 83
9.4. Future work ..... 83
9.5. Conclusion ..... 84
REFERENCES ..... 85
APPENDIX A – “Inexperienced developer” scenario ..... 92
APPENDIX B – “Limited designer” scenario ..... 94
APPENDIX C – Interview questions for scenario evaluation ..... 96
APPENDIX D – Background questionnaire for scenario evaluation ..... 97
APPENDIX E - Background questionnaire for scenario evaluation ..... 99
APPENDIX F – Post-reading questionnaire for scenario evaluation ..... 100

APPENDIX G – Consent form for scenario evaluation ..... 102
APPENDIX H – Consent form for usability tests ..... 104
APPENDIX I – Background questionnaire for usability tests ..... 105
APPENDIX J – Tasks for usability tests ..... 106
APPENDIX K – Post-testing questionnaire for usability tests ..... 107
APPENDIX L – Interview questions for usability tests ..... 109

# LIST OF FIGURES

***Figure 2.1**. Design thinking process structure proposed by Simon [66]. Image provided by Interaction Design Foundation: https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process.....4*

***Figure 2.2**. Types of brainstorming techniques [24, p. 1347] proposed by Faste et al...7*

***Figure 2.3**. PLEX cards designed by Andrés Lucero based on PLEX framework that introduced several categories of playfulness experience. Image is provided by Lucero's personal webpage: http://www.funkydesignspaces.com/plex/.....8*

***Figure 2.4**. Ideation Decks created by Michael Golembewski [31, p. 89].....9*

***Figure 2.5**.Example of persona. Image by Ning Xu on her personal webpage: http://www.ningxu.us/brimlyapp.....9*

***Figure 2.6**. Example of a mind map. Image by Wikipedia: https://en.wikipedia.org/wiki/Mind_map.....10*

***Figure 2.7.** Fashion-related ideas list at HalfBakery ideas bank [34].....10*

***Figure 2.8**. Examples of products invented and developed by using the Quirky [59]...11*

***Figure 2.9**. Example of a Kickstarter project, that Is backed by the community: https://www.kickstarter.com/projects/1654415778/iharvest.....11*

***Figure 2.10**. Homepage of Dribble [21], showcasing some of the user-created content related to web and mobile designs.....12*

***Figure 2.11**. Word tree of Barack Obama's inauguration speech [78].....15*

***Figure 2.12**. New York Times' visualization [3] of tax rates across huge variety of companies based in United States.....16*

***Figure 2.13**. New York Times' visualization [2] of potential paths to victory of US presidential elections.....16*

***Figure 2.14**. Rideship intensity map of Lisbon [68, p. 1119]. Saturated colourful tiles represent high amount of passenger traffic in specified areas.....17*

***Figure 2.15**. Bah´ıa Blanca route, passenger check-ins and bus stops maps [70, p. 32].....17*

***Figure 2.16**. "Driving DNAs" collected from 53 different drivers participated in Fugiglando's study [27, p. 40].....18*

***Figure 2.17**. Developer Experience framework [23, p. 75] that demonstrates three different dimensions of developer's experience – cognitive, conative and affective.....19*

***Figure 2.18**. Wartiovaara's framework [77, p. 5] that highlights the importance and general process of inspiration affecting the outcomes in entrepreneurship.....20*

***Figure 3.1**. LLB On-Board Technical Environment scheme [47]..... 22*
***Figure 3.2**. LLB Developer Portal homepage [17]..... 23*
***Figure 3.3**. "Oma Kokoelma" ("own collection") page showcasing the applications developed by using LLB platform [57]..... 23*
***Figure 3.4**. Examples of Context Cards, describing two different high level concepts within the bus travel experience – entertaining activities and atmosphere of relaxation [39]..... 24*
***Figure 3.5**. Example of Passenger's persona, describing Isac Isolation, a student archetype that prefers to interact with his mobile device rather that with the rest of the passengers [39]..... 25*
***Figure 3.6**. Travel Experience model [39]..... 26*
***Figure 3.7**. Passenger Journey Map [39]. ..... 26*
***Figure 4.1**. Phases of the thesis work and expected outcomes of each of the phases. ..... 27*
***Figure 4.2**. Methods used for each of the phases ..... 28*
***Figure 5.1**. Flowchart of the wireframes for "Inexperienced developer" scenario..... 34*
***Figure 5.2**. Wireframes of introductory (top) and tools selection (bottom) slides. ..... 35*
***Figure 5.3**. Wireframes of the developer's (top) and designer's (bottom) introduction pages..... 36*
***Figure 5.4.** Wireframes of pages, representing basic structure of Travel Experience Model and its content. Includes Travel Experience Model page (top), Physical Context page (middle) and Air Quality subtheme page (bottom). ..... 37*
***Figure 5.5**. Sensor data visualization are presented in a form of suggestive text, randomly generated from existing sensor data. ..... 38*
***Figure 5.6**. Flowchart of the wireframes for the "Limited designer" scenario..... 38*
***Figure 5.7**. Wireframes of introduction slide (first), Toolkit offering selection (second), Persona search (third) and Persona page (fourth)..... 40*
***Figure 5.8**. Sensor data visualization in the second set of wireframes is presented in a form of another suggestive text. ..... 40*
***Figure 5.9**. Post-reading questionnaires mean values for the "Inexperienced developer" scenario (N=10). ..... 42*
***Figure 5.10**. Post-reading questionnaires mean values for the "Limited designer" scenario (N=10)..... 43*
***Figure 6.1**. Redux framework website layout. ..... 49*
***Figure 6.2**. Original flowchart of LLB infrastructure with integrated prototype. Yellow elements are integral parts of the prototype..... 51*
***Figure 6.3**. First flowchart of the prototype with actual UI mock-ups. ..... 53*

***Figure 6.4**. Passenger Persona page. ..... 54*
***Figure 6.5**. Travel Experience Model page. ..... 55*
***Figure 6.6**. Context page. ..... 56*
***Figure 6.7.** Passenger Journey Map page. ..... 56*
***Figure 6.8**. Context Cards page. ..... 57*
***Figure 6.8**. Bus Sensor Data page ..... 58*
***Figure 6.10**. Glossary page. ..... 59*
***Figure 6.11**. Resources page. ..... 60*
***Figure 6.12**. Introduction page. ..... 61*
***Figure 7.1**. Mean and standard deviation values for questionnaire section related to novelty properties of the prototype (N=8). ..... 65*
***Figure 7.2**. Mean and standard deviation values for questionnaire section related to Toolkit materials pages properties (N=8). ..... 66*
***Figure 7.3**. Mean and standard deviation values for questionnaire section related to sensor data visualizations (N=8). ..... 66*
***Figure 7.4**. Mean and standard deviation values for questionnaire section related to prototype navigation (N=8). ..... 67*
***Figure 7.5**. Mean and standard deviation values for questionnaire section related to layout of the prototype (N=8). ..... 67*
***Figure 7.6**. Mean and standard deviation values for questionnaire section related to visuals of the prototype (N=8). ..... 68*
***Figure 7.7**. Mean and standard deviation values for questionnaire section related to terminology (N=8). ..... 68*
***Figure 7.8.** Mean and standard deviation values of prototype satisfaction ratings (N=8). ..... 71*
***Figure 8.1**. New persona introduction page - enriched with short previews of each of the personas. ..... 73*
***Figure 8.2**. New persona page - received changes to a highlighted area that contains tooltips and more connections to other materials. ..... 74*
***Figure 8.3**. New model page – simplified and streamlined for a better clarity. ..... 75*
***Figure 8.4**. New context page – new element grouping and simplified visuals. ..... 75*
***Figure 8.5.** Journey Map page did not changed much from the previous iteration as participants did not have any issues with it. ..... 76*
***Figure 8.6**. Context Cards page received a functional gallery for better view of their content. ..... 77*
***Figure 8.7**. More refined visuals of the bus sensor visualizations - collapsible sensor blocks and compact parameter view. ..... 78*

***Figure 8.8**. Glossary page did not receive any major changes.* ..... *79*
***Figure 8.9**. Introduction page is now more interactive and streamlined.* ..... *79*

# LIST OF ABBREVIATIONS AND SYMBOLS

HSL - Helsingin seudun liikenne (Helsinki Regional Transport company)

LLB – Living Lab Bus, a project funded by Business Finland in 2015-2019

API – Application Programming Interface

SPA – Single-Page Application

DevEx – Developer Experience, a term introduced by Fabian Fagerholm et al.

# 1. INTRODUCTION

This chapter explains the motivation behind this thesis work, its goals, scope and structure.

## 1.1. Motivation and background of the research

There is no doubt that the public bus transportation is a crucial part of any city infrastructure. In order to keep the quality of the transportation services and experiences, innovations and new ways of creating various solutions are in order. For the most part, the entire development of such services is handled by transportation organizations (e.g. Nysse [71] in Tampere, Finland). Publicly, there is no proper and open practical tool to create more personal or more contextualized solutions and there is a certain lack of access to accumulated knowledge base of the bus transportation infrastructure. Developers and designers have to rely on available information and technical specifications that companies and organizations allow to make public. There is a certain need for a public tool that would help developers and designers with understanding of specifics of bus transportation and actual service development. Further more, lack of publicly available inspiration and design resources related to the bus transportation also creates opportunities to explore potential solutions and answers to this concern.

Living Lab Bus [47] is one of the projects that focuses on discovering new horizons regarding new travel experiences. LLB offers an open development platform that enables ideation, design and prototyping processes for bus related solutions. At this moment LLB is operating within Pirkanmaa and Uusimaa regions of Finland and is collaborating with Helsinki Regional Transport (*Helsingin seudun liikenne,* or *HSL* in Finnish) [35] and local governmental bodies of Tampere and Helsinki.

This platform is co-funded by Business Finland and other partners (Linker, Aleco, Foreca, PayiQ and EEE) and co-developed in collaboration with various research organization, such as Tampere University (Central and Hervanta campuses) and Aalto University and is coordinated by VTT Technical Research Center. In this tandem, Tampere University (Hervanta Campus) is focused on end-users (passengers), their

experiences in regard of expectations for public bus transportation services and measurement of their satisfaction from said services.

Project delivers insights of the travel process in context of passenger experiences in a various forms. Bus Travel Experience Toolkit was designed and developed during the project and contains following design tools: Context Cards, Passenger Personas, Bus Travel Experience Model and Passenger Journey Map. These tools and related topics are described in Chapters 2 and 4 of this thesis.

Among project's offerings, Living Lab Bus Technical Environment was setup. It contains a fleet of 3 heavily supplemented with sensors electric buses operating in Helsinki on. LLB also offers various APIs to access sensor data in real-time and for a specific date.

This thesis work explores the idea of integration and incorporation of Bus Travel Experience Toolkit and bus sensor data visualization into Living Lab Bus platform.

## 1.2. Goals and the scope of the research

The goal of this thesis work is to integrate sensor data, its visualizations and Bus Travel Experience Toolkit into Living Lab Bus development platform. The purpose of such task is to motivate and support developers in their ideation process for their own solutions in the field of bus transportation. In order to perform this, following questions needs to be discussed:

**RQ1**: What kind of design materials can be considered useful for developers' ideation process?

**RQ2**: In what form can sensor data visualizations support and motivate developers to ideate?

**RQ3**: How can combination of design materials and visualizations be integrated into Living Lab Bus and presented to the developers?

First question is targeted towards the discovery of what kind of artefacts or inherent properties of the given Toolkit would be useful for the software developers and their ideation process. This question is not focused on evaluation of the ultimate usefulness of the Toolkit, but exploration and definition of its attribute space in order to establish rules and guidelines that would help developers to successfully utilize the toolkit.

Second question is focused on other half of the goal – data visualization and its format that could serve developer's ideation process. It is necessary to set a clear vision of

what kind of information can be extracted from bus sensor data and in what way it can be shown to the developers.

Last question revolves around general idea of combining both Toolkit and sensor data visualizations and presenting it together. It explores the design space and practical application of the data from the developer studies.

The result of the thesis work would be a certain web portal that can be integrated into the Living Lab Bus structure and contribute to the platform as an insightful instrument for ideation and inspiration for the software developers and other users of the platform.

## 1.3. Structure of the thesis

This thesis work includes 9 chapters. Chapter 2 explores relevant studies and literature related to the topic of the thesis work. Chapter 3 introduces practical background and context of the study – Bus Travel Experience Model and Living Lab Bus' Developer Portal. Chapter 4 describes all the methods of data gathering and analysis that were used during this research. Additionally, it elaborates research schedule and phases. Chapter 5 delivers the description of the first developer study – scenario evaluation – and its participants, procedure, materials and findings. Chapter 6 describes the design and implementation approaches to first proper version of the Toolkit prototype based provided feedback of scenarios. Chapter 7 presents the results of prototype usability tests as well as their procedure and participants. Chapter 8 introduces prototype revision based on feedback from usability tests, and delivery of it to Living Lab Bus. Chapter 9 discusses major findings and future work and concludes the thesis. List of references and appendices are located after chapter 8 in the final chapters of the thesis.

# 2. THEORETICAL BACKGROUND

This section takes a deeper look at the theoretical basis of this thesis. In order to do that, it is necessary to take a look at the previous works related to its topics. The purpose of the this work is to explore the ways to help developers to ideate with the mentioned Toolkit and thus, this thesis touches several concepts. Major concept is *ideation* and specifically the importance of idea leveraging, inspiration, ideation tools and their role in design. Thesis work also takes a look to *passenger* and *bus travel experiences* in the context of ideation. Research additionally explores the field of *data visualization* in the context of public transportation. In the end, research considers *developer experience* as one of the major topics and significance of developer's perception.

## 2.1. Ideation and inspiration

Ideation is often being referred as a design activity and as a process of generating and formatting new idea and it plays a major role in the innovation and, more importantly, in design thinking process. Design thinking was introduced by Herbert Simon in his work "The Sciences of the Artificial" (1969) [66]. His definition of the design was "…*courses of action aimed at changing existing situations into preferred ones*" and he proposed a multistep structure to this process (Figure 2.1), calling it as design thinking. This structure is used nowadays and a lot of scientific works that are trying to explore the properties and structure of the design process are based on his work.

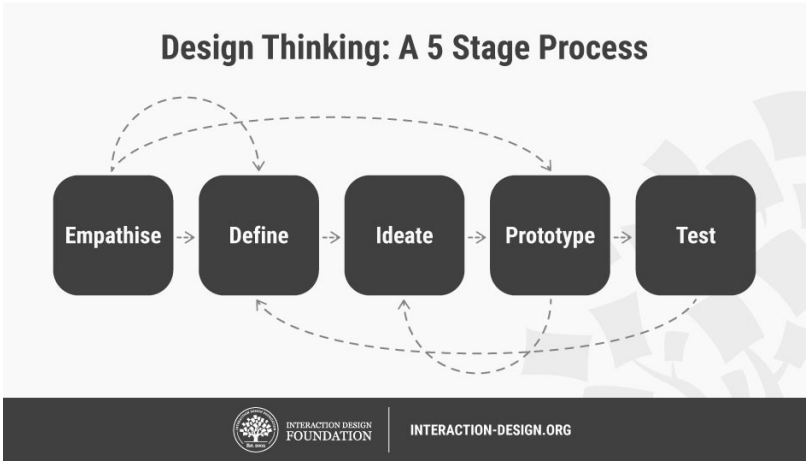



***Figure 2.1**. Design thinking process structure proposed by Simon [66]. Image provided by Interaction Design Foundation: https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process*

Ideation takes an important place right in the middle of the process. It plays a transitive role between stating a problem that needs to be solved and prototyping and testing an actual solution for it. During this phase, designers and creators generate ideas and define the scope of the solution to the stated problem. This model also tells us that ideation cannot be initiated without some basis or inspiration as it needs some question or a problem. Inspiration is a major driver of the idea creation and takes many forms. In psychology [74], inspiration is a positively charged occurrence that may be evoked by a certain trigger or stimuli. That stimuli will drive or motivate person to take some action as a response to that stimuli. Inspiration is also generally associated to an optimism, high self-determination and self-esteem that are caused by said evocation. This leads to generation and realization of a more peculiar idea than idea that was generated purposefully and consciously [74]. When it comes to a general creative process, creators can derive or be influenced by artwork [20], sounds, situations, experiences of self and others, creator's own knowledge base and other various items. Creators use *artefacts*, or entities that represent specific properties of an object, situation and other, as a basis for their decision-making. These artefact may serve the purpose of said triggers that fuel pure inspiration causing more creative outcomes of ideation process.

The topic of influence of the certain artefacts over design thinking was explored by a vast number of studies that tried to measure it. In one study [12], designers were exposed to some thematic images of human figures or items, from which they remembered mostly images of a beer mug, white-collar male and a child. Those images influenced designers' state of mind during their next task of restaurant signboard design. As a result of such influence, most of them chose to design signboard for bar, beer house and kid's restaurant. This exposure to the images created an association between most memorable images and task theme and, as an outcome, served as a starting point for ideation.

Some studies went to a slightly different direction and tried to define and evaluate whenever ideation occurs to be intrinsic and when it is being "forced". It may indicate that there is a significant importance of having an vast set of solution examples to motivate people to start coming up with ideas. Work of Siangliulue et al. [64] described the process of example selection and how showing these examples to participants may have influenced ideation process in general. As a result, participants of the study that had no prior knowledge of the examples were able produce less creative ideas than those who was inspired by diverse examples. Study also demonstrated that having a common theme between example sets generates better results. Similar studies also reveal that common theme of the examples and ideas is vital for a successful and

productive creative process [45]. But provision of the examples itself sometimes is not enough as there is a noticeable difference in their use cases. For example, possessing an idea of your own and being able to find an alternative to that idea in provided examples produces much better results than starting from a blank state under the same conditions [65].

Examples may not only trigger the ideation, but can also help to understand the bigger picture of the any present environment, e.g. when designing new product for the market that already has similar products [36]. In addition to that, examples also may serve as a comparative tool and creators may use to evaluate own ideas against it. They may provide enough context and data to use them as reference points for the idea evaluation and comparison [36].

Idea evaluation also plays a fairly big role in design thinking process. Some studies proposed specific taxonomies in order to formalize and streamline idea definition [41]. When generating and evaluating ideas, It is also important to support some sense of continuity. Generated ideas can serve as a fertile ground for the future ones. It indicates a certain level of *richness* of a certain idea [69]. It brings additional value to the idea as it opens up new perspectives and themes that can inspire people to look for other solutions as well.

Importance of comparisons does not stop on evaluation of properties of some ideas. The creators have to have some basis on which they realise whenever they need help with creative process. It brings up the question understanding of the design process that led these ideas to transform into some tangible outcome. In order to understand the process pure inspiration is not sufficient. There are numerous formal techniques, methods and various set of tools being used to translate inspiration into understandable and usable format.

### 2.1.1. Ideation methods, techniques and tools

For the past decades, designers and researchers have come up with plenty of ideation and collaborative design tools as well as established approaches and techniques. Smith [67] identified 172 different methods of ideation and due to this amount, this thesis work will focus only on some of them.

Standard brainstorming is one of the most popular techniques that require small amount of effort to conduct. Typical brainstorming session involves idea generation phase, during which participants are proposing and recording large amount of raw, untested and spontaneous ideas. Brainstorming also has a specific code of conduct

that excludes critique of the proposed ideas due to its purpose of creating a large pool of ideas within some area of interest.

Faste [24] (Figure 2.2) et al. proposed some variation to the typical brainstorming sessions for both online and offline. Chainstorming is basically a brainstorm with established online communication channels. Cheatstroming is mostly focused on leveraging the ideas from previous sessions and complete exclusion of idea generation phase. Tweetstormer refers to a digital format of the session and usage of an application that analyses ideas formed during cheatstorm.

Reverse brainstorming takes different approach as its purpose is to go in an opposite direction and discover potential flaws and limitations in the design rather than its advantages.

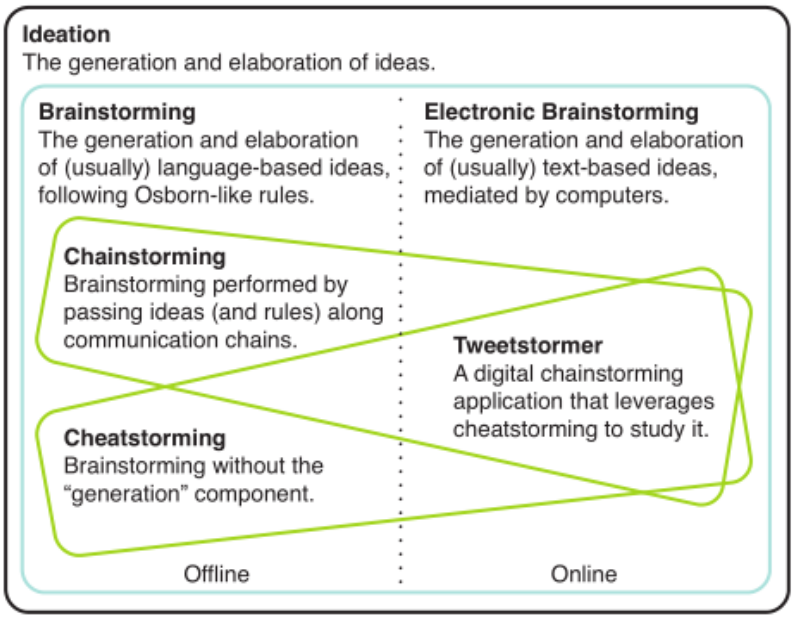



***Figure 2.2**. Types of brainstorming techniques [24] proposed by Faste et al.*

*Card-based tools* are fairly popular instruments for collaborative design and they had proved to be useful for ideation in brainstorming sessions. Generally, these cards take form of cards with thematic images and text that describe some high level concept and serve as sources of inspiration. For the most part, such cards are used in a physical format. Though the format of the cards does not necessarily mean that it would influence the outcome of co-design sessions. Whether it is physical or digital or both formats, their usage promises similar results [49]. Creators can utilize them in different ways: combine them with each other to present some complex ideas or simply use them a visualization tool to communicate with other co-creators. PLEX, or Playfulness Experience cards is one of widely known tool. They were created by A. Lucero [48] et

al. and are available in a physical format. These cards are based on Playfulness Experience framework that was designed by Arrasvuori [5] to explore fun factor and pleasantness of the product, mostly related to various types of games. Cards represent 22 different categories of playfulness introduced with the framework, and are shown on Figure 2.3.


***Figure 2.3**. PLEX cards designed by Andrés Lucero based on PLEX framework that introduced several categories of playfulness experience. Image is provided by Lucero's personal webpage: http://www.funkydesignspaces.com/plex/*

Ideation Decks [31] (Figure 2.4.) are trying to achieve similar goal of providing a visualization tool that would serve as a source of inspiration. General theme of those cards is exploration of full spectre of emotions while using technology at home.

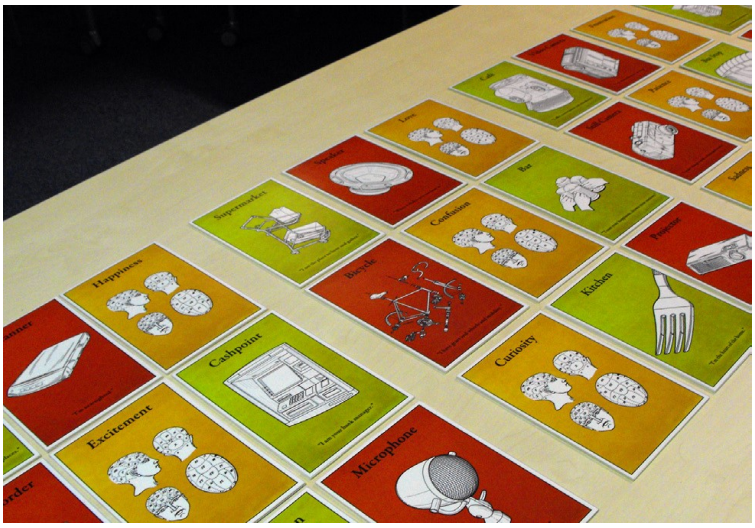



***Figure 2.4**. Ideation Decks created by Michael Golembewski [31].*

Some of the tools can serve as a reference material, such as Journey Maps and Personas. Journey Maps can be used for ideation in experience-driven design. This tool breaks down a use case scenario into a sequence of actions and tasks user may perform and specifies what kind of emotion and experience it is expected from the user at each action and task. One of the variations to Journey Maps is a customer journey maps that is focused on experiences through companies and their services.

Personas (Figure 2.5) were created by Alan Cooper [15] and serve as archetypes and representation of a potential target audience or its part. This tool represent key traits, needs and other properties and characteristics of presented sample of audience. Personas can also be extended and enriched with user scenarios describing flow of some activity or everyday situation. This tool can be used in brainstorming sessions when exploring and establishing goals, key touchpoints, use cases and general solution space of some product.

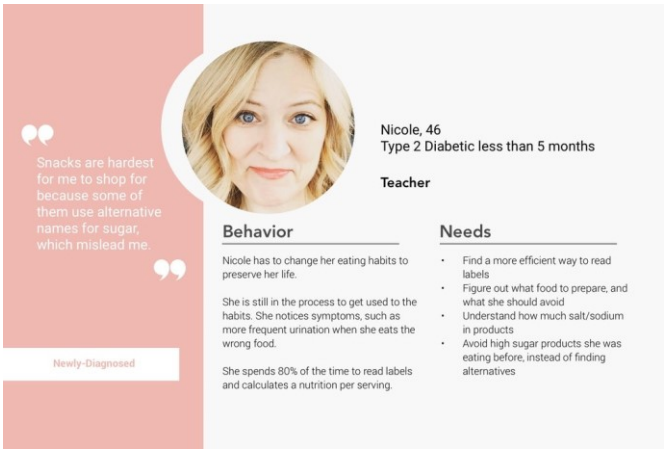



***Figure 2.5**.Example of persona. Image by Ning Xu on her personal webpage: http://www.ningxu.us/brimlyapp*

Mind maps (Figure 2.6) are also widely used tool. Creation of a mind map involves listing a set of words related to some area of interest and marking relationships between said items. Mind map takes form of a hierarchical diagram like a word tree.

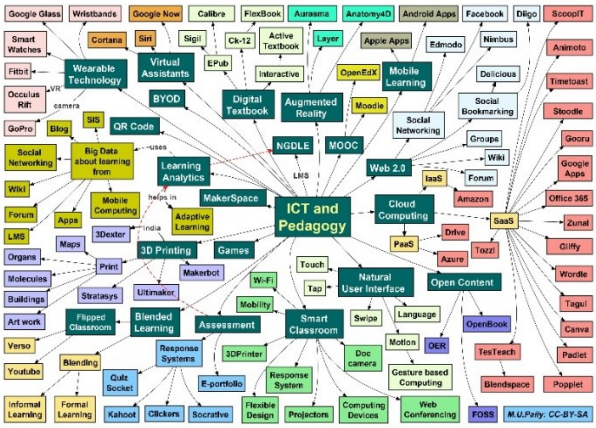



***Figure 2.6**. Example of a mind map. Image by Wikipedia: https://en.wikipedia.org/wiki/Mind_map*

Some types of tools are used to facilitate an ideation process. One of those types deserves a separate mention – ideation platforms.

### 2.1.2. Ideation platforms

*Ideas banks* is one of the most basic and streamlined platform type there is. They serve as a storage of the thousands ideas divided into thematic categories. User can utilize these ideas or even contribute to the set. For examples, HalfBakery [34] provides a vast catalogue of ideas related to various topics such as business, product design, fashion, science, politics, sport and many other. Figure 2.7 shows the example of fashion-related items.

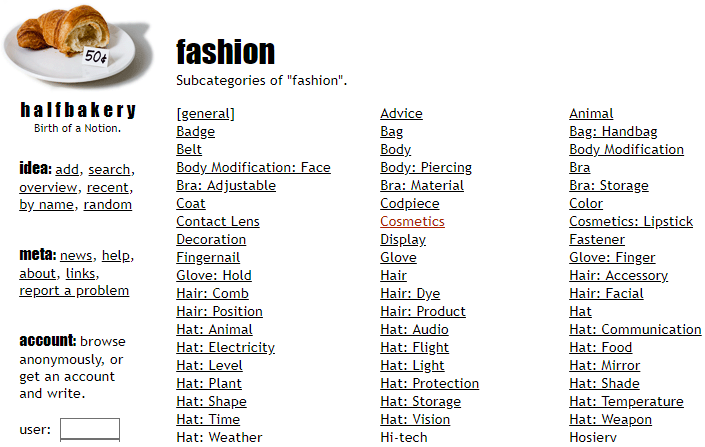



***Figure 2.7.** Fashion-related ideas list at HalfBakery ideas bank [34].*

*Invention platform* such as Quirky [59] or Viima [76]. is a type of a platform that enables creators to invent by providing a facilitating digital environment where they can be in constant contact with manufacturers and product designers. Figure 2.8 shows the result of such collaboration by using Quirky's solution.

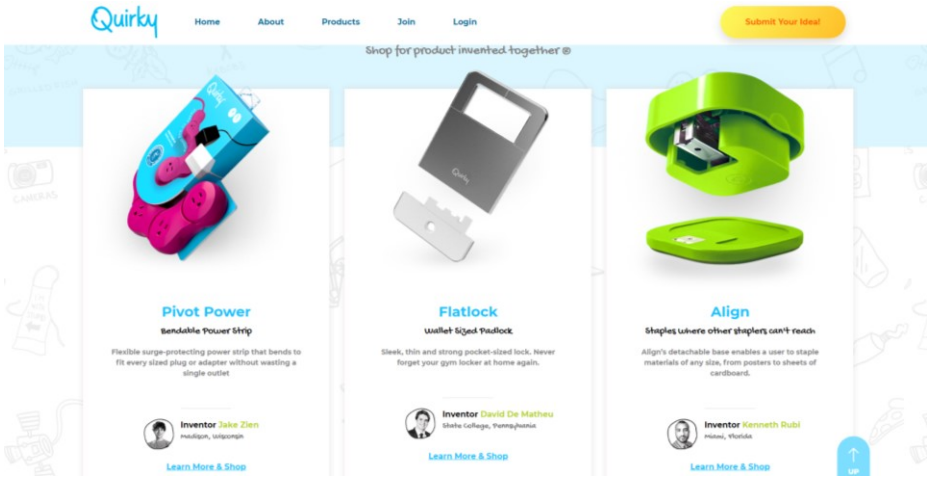



***Figure 2.8**. Examples of products invented and developed by using the Quirky [59].*

*Crowdfunding platforms,* such as Kickstarter [44], offer crowdfunding functionality and may be considered as idea evaluation tools where people can financially support the project that represents ideas interesting or important to them personally. Creator is able to pitch his idea publicly and supporters, or so called backers, are able to donate money until project reaches a certain margin. Downside of this approach is that such platform ensure the financial stability of the creator only during product design and development. The result and its financial, political and social success is generally out of scope of such platforms. Figure 2.9 demonstrates an example of a project that was heavily supported as people got interested in the pitched idea.

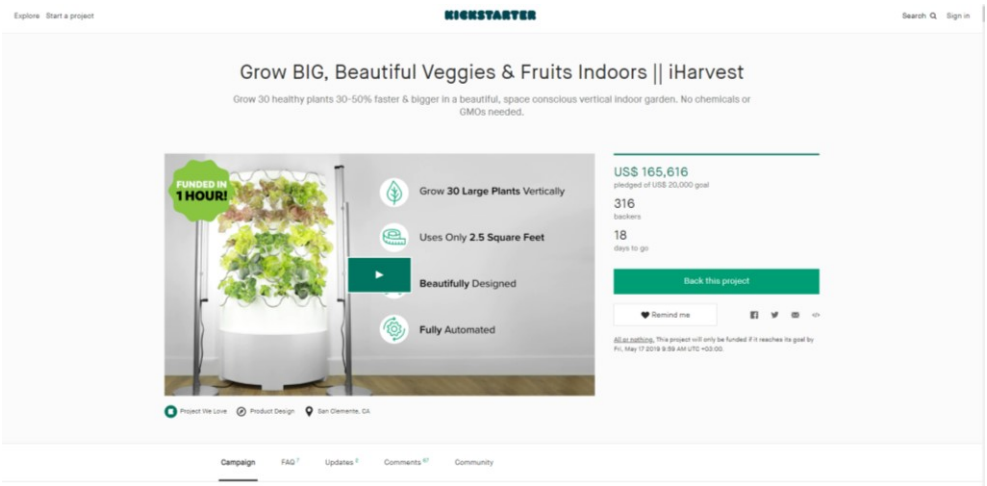



***Figure 2.9**. Example of a Kickstarter project, that Is backed by the community: https://www.kickstarter.com/projects/1654415778/iharvest*

*User-created content platforms* and communities also serves as sources of inspiration and examples. Dribble [21], Behance [8], ArtStation [6], DeviantArt [18], CollectUI [14] – they all provide similar functionality of sharing user-created artwork, web and graphical designs and other digital content. These platforms allow creators to have an access to thousands of works and discover an increasingly vast set of examples they can derive from or be inspired by. Figure 2.10 shows Dribble platform and its showcasing functionality.

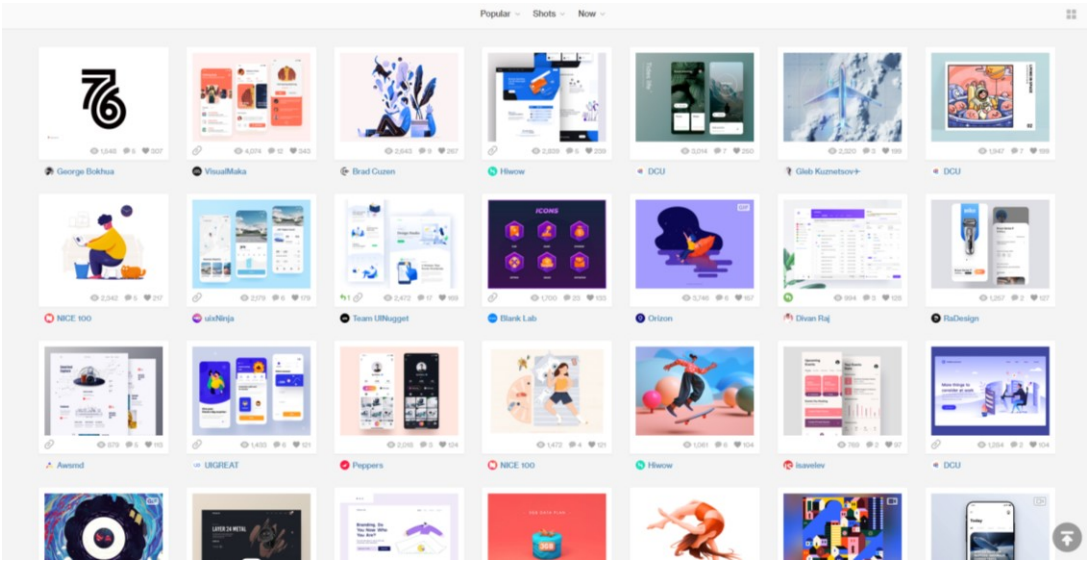



***Figure 2.10**. Homepage of Dribble [21], showcasing some of the user-created content related to web and mobile designs.*

*Public talks* can also inspire people or motivate them enough to start creating something new. For example TED [72], a non-commercial organization created by Richard Saul Wurman in 1984, allows scientists, artists, musicians, writers or practically anyone to perform a public talk in a 18-minute format on any topic they wish to talk. Recordings of these talks are publicly available on video hosting and streaming services like Youtube.

## 2.2. Bus Travel and Passenger Experiences

The importance of innovation in public transportation cannot be stressed enough. Transportation is a lifeline of the living areas and constant improvement seems to be in order. Some might even argue that public bus transportation is practically a “face” of the city [26]. It indicates the importance of ensuring of a proper travel experience. One way of doing it is to generally improve basic bus services like providing high-tech bus stops and electric buses, timetable availability, mobile route planners, ticketing services and other.

The other way is to take a deeper look at the pillar of the travel experience – the passenger. Aside from everyday bus activities and interactions with the usual transportation services, passenger tend to perform various digital tasks during the travel, e.g. listening to music or checking social media [50]. Therefore, there is a lot potential for enhancing the travel experience by delivering services that accompany the travel experience [9].

Passenger perception and expectations from the transportation services varies with the choice of the transportation mode. It raises the question of the passenger expectations bus transportation companies and service designers need to consider. It may allow to gain necessary context to the bus service ideation process in order to streamline it. Henceforth, it may even help to create a wide range of solutions targeted to incentivize the usage of public transportation not only among those not using it, but also among those who prefer personal means of transportation instead [7].

Hildén et al. [38] introduced over a hundred different statements based on Tampere and Helsinki passengers' responses. These statements formed several themes and categories of passengers expectations from bus services: *importance of ecological values, more information and engaging activities at the bus stops, atmosphere or relaxation, possibility of a social interaction* and *premium experience that are typical for bus services*.

Those insights were later used to create a set of ideation tools eventually forming a Bus Travel Experience Toolkit [39]. The Toolkit consists of four different inspirational materials. Passenger Personas introduce passenger archetypes with each of their own traveling habits, age group and usage of the digital services along the bus travel. Context Cards [37] represent several bus-related high level ideas in a format of thematic cards. Passenger Journey Map [39] shows major actions an average passenger performs in everyday bus travel situation. Bus Travel Experience Model [40] covers the entirety of possible contexts and themes that surround travel experience in a visual format. The Toolkit is described in a greater detail in Chapter 3 of this thesis work.

This Toolkit is a great example of how complex and diverse information can be visualized and strained out in a more accessible and holistic format. Toolkit raises the importance of data visualization in a way it could support ideation and inspire people to create new solutions in the field.

## 2.3. Data visualization

Data visualization is a visual language that presents some information in accessible and coherent visual format. For the past decades, data visualization gained large amount of significance in the context of inspiration and sensemaking, a process of constructing and organizing the knowledge [63].

Visualizations are especially big in data science, where semantics and sensemaking play major roles in data analysis [39] and there is a definite need for a human-computer facilitation during ideation processes. Importance of such facilitation is highlighted by some as big portion of researches is focused on idea evaluation via analysis of quantitative properties of ideas like similarity of the text or some rating system [51]. Some researches are trying to break through this situation by developing semantic-based exploratory tools that visualize the ideation process and involve a human being during evaluation phase [51][29].

Others argue that visualization can help ideation and sensemaking processes from a bottom-up approach, continuously increasing the understanding of some subject [10] and thus, motivating the creator. Some propose to introduce certain metrics and paradigms that solidify result of some ideation process in a visual composition format [43].

Visualizations are obviously very data specific and it is quite a challenge to specify all techniques that were used across entire centuries as well as types and formats [11].

### 2.3.1. Data visualization principles and examples

Despite the fact that visualizations require a very strict context to convey some information, there are some general principles of visualization that are possible to outline. Chen et al. argue that graphics are used to either present or explore some information or a dataset [11].

Large amount of visualizations are graphic-based and not purely textual. Rich graphics may supplement and make the text more readable and easier to understand, but they rarely work on their own outside decorative illustrations [11]. On the other hand, there are plenty of cases of visualizations where text works completely alone like basic table with highlighted headings for statistical data. One of most unique examples is a Word Tree [78] that creates a hierarchy of some text sample based on how often a certain word is used within text body. Figure 2.14 demonstrates such hierarchy that breaks down former USA president Barack Obama’s inauguration speech. This is a good

example of exploratory (or analytical) visualization, user can come up with own conclusions based on presented data since Word Tree is not concluding the information in any way.

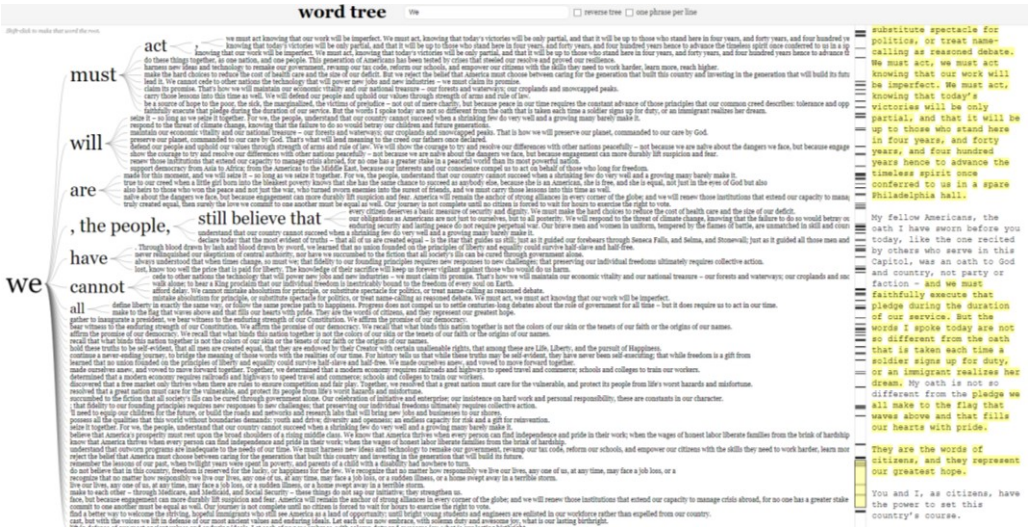



***Figure 2.11**. Word tree of Barack Obama's inauguration speech [78].*

The choice of the graphics and visual elements is entirely based on data and properties of this data that are important to show at given moment [11], like a pie charts to represent shares or a histogram to show distribution of some numerical data. Several major US newspaper publishers like New York Times or Washington Post are fairly famous for their approaches to visualize their vastly diverse textual and statistical content. They approach to the collected data from a presentation standpoint as they use those visualizations to inform their readers about some event or interesting statistics. For instance, like presenting tax rate data across various US-based companies [3] (Figure 2.15) or hierarchical tree of all potential paths to presidential election victories based on hypothetical victory in specific states (Figure 2.16) [2].

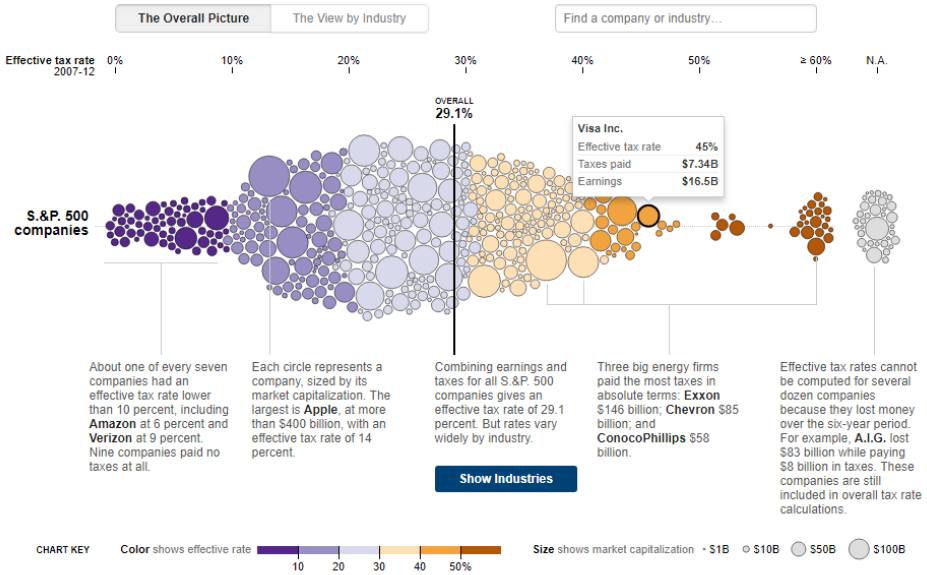



***Figure 2.12**. New York Times' visualization [3] of tax rates across huge variety of companies based in United States.*

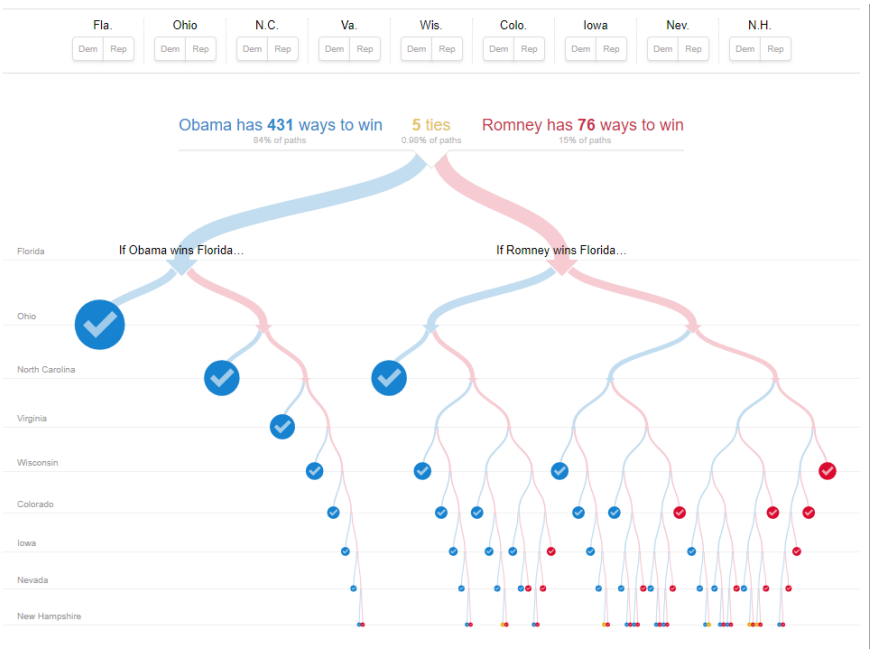



***Figure 2.13**. New York Times' visualization [2] of potential paths to victory of US presidential elections.*

### 2.3.2. Bus data visualizations

In the context of public bus transportation, approaches to data visualization vary greatly – from basic route viewers [56] to proper data analytic tools. Quite a few studies draw their attention to the presentation of a city-wide overview of the traffic situation in various views by using generic heat maps, traffic maps, line charts, time scales, choropleth maps and other modes. Large amount of the conducted studies are aimed

at the presentation of mostly statistics or sensor data while lacking some holistic overview leaving the conclusion building to a human.

One of the most widely usable format for that purpose is a map-based one. One study conducted in Lisbon, Portugal [68], researchers come up with several modes of the city map showing different types of data. Figure 2.17 shows 3D map of Lisbon's rideship – intensity of bus passenger traffic in various areas of the city. Other study [70] presented similar tool for Bah´ıa Blanca, Argentina, presenting 4 modes for a city map view (Figure 2.18) – bus and routes, passenger check-ins and bus stop views.

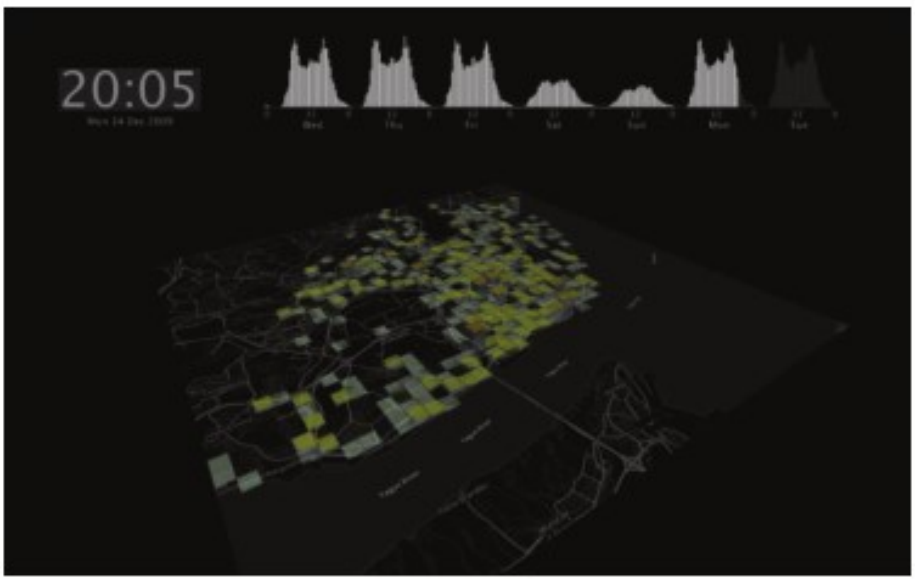



***Figure 2.14**. Rideship intensity map of Lisbon [68]. Saturated colourful tiles represent high amount of passenger traffic in specified areas.*

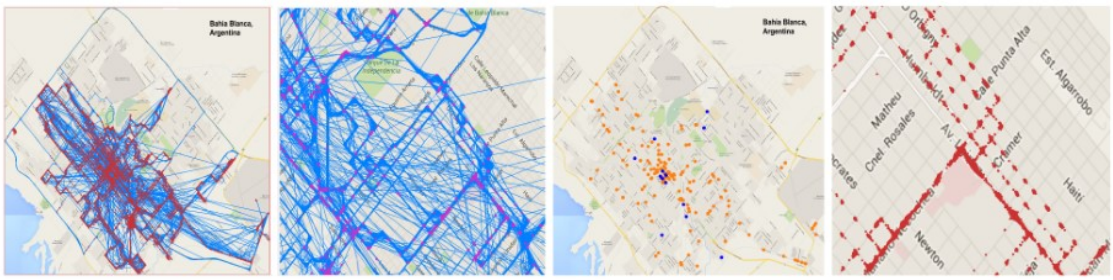



***Figure 2.15**. Bah´ıa Blanca route, passenger check-ins and bus stops maps [70].*

One of the most interesting ways to interpret quantitative sensor data from buses is to present it in a qualitative manner. For example, the concept of "Driving DNA" [27] is focused on collecting large data samples of bus sensor data in order to evaluate driver's driving habits and behaviour (Figure 2.19). Visualization is based on quantitative data in 4 different dimensions, or so called "genes" (braking, turning, speeding and fuel consumption) with a rating scaling from 1 to 5 (best score). This

present a holistic view (“driving DNA”) of the driver’s behaviour while driving and enables a decision-making factor as it clearly present the result of the driving session.

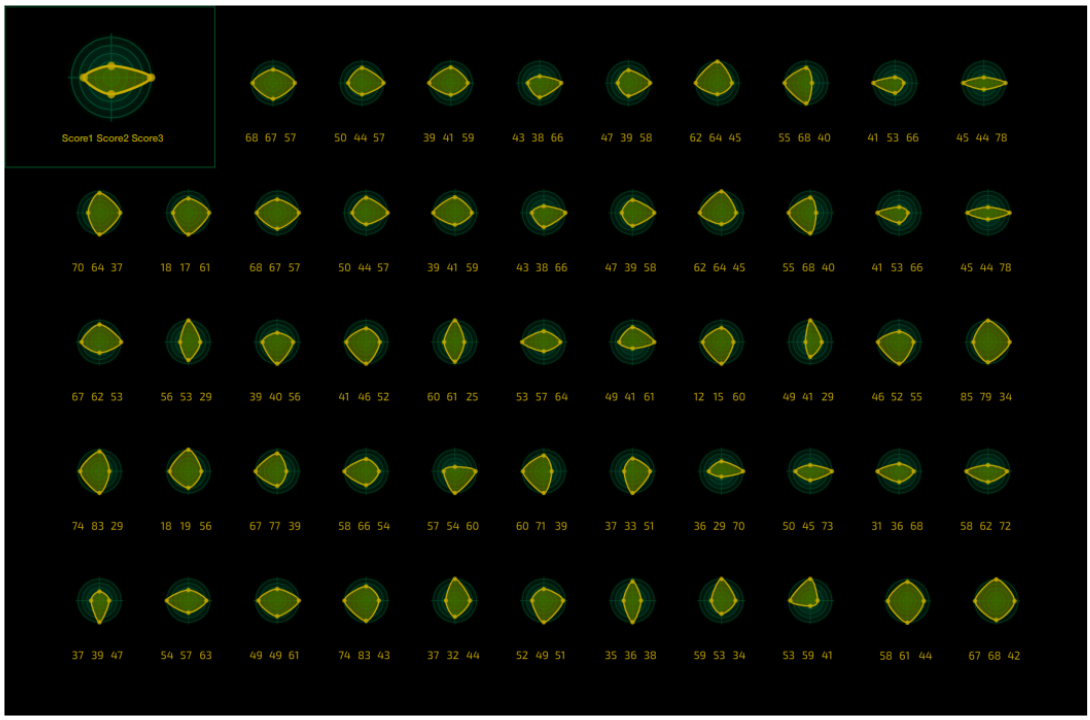



***Figure 2.16**. “Driving DNAs” collected from 53 different drivers participated in Fugiglando’s study [27].*

## 2.4. Developer experience

Developer experience (or DevEx) is a quite fresh advancement in the field of user experience. A large amount of works related to DevEx study specific usability properties of software like integrated development environments, or IDEs, programming languages, platforms and other supporting infrastructure [19][53].

Several studies take more of a holistic view on issues raised within developer’s work processes like reasoning behind various different instances of technical debt during the project development [4]. Other take a deep dive into subject of software cohesion and difference of perception of a term between experts and novice developers [16].

But quite limited amount of studies were conducted in relation to an actual developer’s emotional experiences, psyche and general psychological and behavioural insights. One of the early works explore and speak against the notion of code being the only valuable part of overall developer’s experience and contribution [13]. Coatta states that processes and experiences that developer undergoes along the way are as much valuable.

The actual term “developer experience” was introduced by Fabian Fagerholm et al. in their work [23] regarding developer’s perception, experiences, mindset and ways of operating within software development activities. In this work, they created a framework that gives a holistic view of the developers’ experience (Figure 2.20). He divided it into three different dimensions – cognitive, conative and affective dimensions – that illustrate three different sets of artefacts and experiences. Cognitive dimension is based around developer’s perception of the tools, skills and infrastructure. On the other hand, conative part leans towards value of developers’ work and contribution, their motivation, goals and willingness to reach them. Affective dimension contains insights of the social environment and general feeling about one’s work like sense of belonging to the team, respect or atmosphere in work environment.

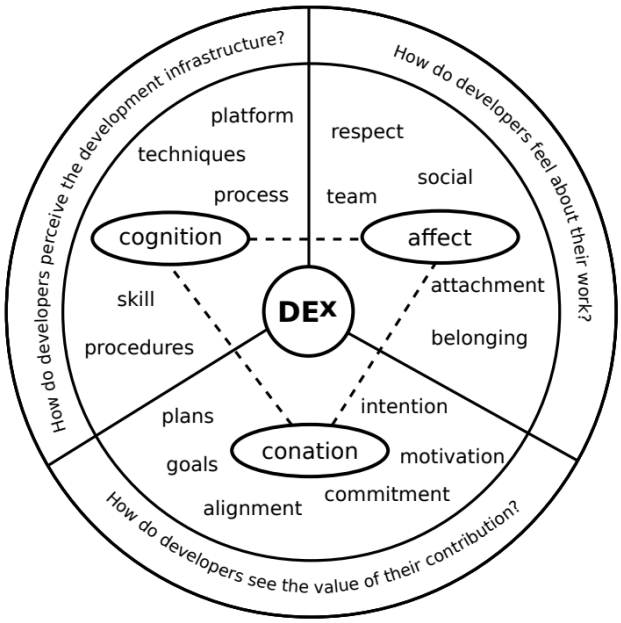



***Figure 2.17**. Developer Experience framework [23] that demonstrates three different dimensions of developer’s experience – cognitive, conative and affective.*

Inspiration in general plays a great role in developer’s ability to perform. There are studies [25] that explore potential range of factors that influence DevEx within software development areas, e.g. software engineering for mobile devices.

Before diving in into DevEx specifics and attributes, it is possible to take a look at some of the underlining concepts of inspiration within the context of business and entrepreneurship. Wartiovaara [77] et al. introduced a framework (Figure 2.21) that highlights the importance of inspiration in entrepreneurship and a lot of it overlaps with Fagerholm’s DevEx framework.

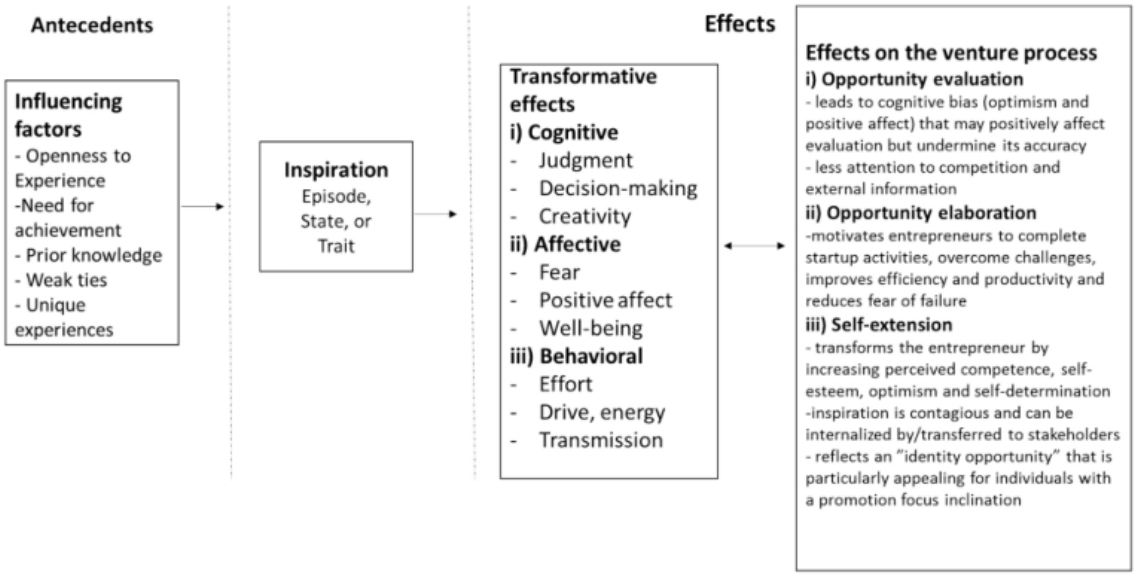



***Figure 2.18**. Wartiovaara's framework [77] that highlights the importance and general process of inspiration affecting the outcomes in entrepreneurship.*

He argues that inspiration has a transformative effect on a person's motivation that can communicate into different outcomes. It matches with Fagerholm's statements describing the impact of certain factors on motivation that affects developer's performance like lack of contribution or need for an achievement.

Further analysis of DevEx-related studies can shine some light on more similarities. Various external and internal to developer factors have a great impact on the working experiences (like willingness to accept new experiences stated by Wartiovaara). But there is a certain array of these factors that are quite specific in case of software development. Not being able to solve some specific problem has the most common occurrence in the software development due to its focus on problem-solving. This might be soul crushing experience and major demotivator for many. Team and process-related concerns are following, for example project time constraints, poor code quality and work ethics of one's peers [32].

Collaborative development tools are meant to resolve some of the related issues, like GitHub [73], a cloud-based development platform and version management system that enables teamwork, code sharing and collaborative problem solving and became one of the most widespread tools in the industry. Other tools are related to the processes such as [75], a digital sticker board that is used for project and process management. Some tools are trying to achieve both, such as CORED and for the most part it managed to reach its goal to enhance teamwork and increase developers' motivation. [58]. Inability to address aforementioned issues may lead to a certain problems both external and internal for developer, such as lack of motivation and

productivity, lack of an adequate technical equipment and infrastructure, excessive intellectual efforts. These can cause an immense decrease of work quality as well as having a personal impact of the developer's contribution and health [33].

## 2.5. Summary

Presented studies underline the importance of inspiration in design process. Various artefacts and factors have a different impact on ideation outcomes. Thus, it is essential to deliver a proper infrastructure that would support ideation in order to ensure the quality of generated ideas. In the corner of the that provision is the establishment of connection between suggested tools, processes and artefact and it is usually done by providing some certain theme or common high level idea.

Data visualization techniques and principles are important part of the ideation as they simplify the understanding of some information. Therefore, contextualized graphics and texts can help to enhance decision making process by either presenting some data to the target audience with intent to inform people or give them enough context for them to start exploring it on their own and eventually coming up with their own conclusion.

In the field of software engineering, perception of said infrastructure can also influence the outcomes of creative and development processes. Henceforth, tools creators must understand the specifics of such perception and plan for unexpected expectations in advance.

This thesis work explores developer perception and expectation for Bus Travel Experience Toolkit and it is important to map it in the research space. Thus, by using a Fagerholm's framework for developer experience, thesis can be set up within its cognitive dimension.

# 3. PRACTICAL BACKGROUND

This chapter introduces practical context of this thesis work – Living Lab Bus' Developer Portal and Bus Travel Experience Toolkit. These tools were used a basis for the empirical part of the thesis that was focused on utilization of Developer Portal offerings (access to a bus sensor data API) and improvement of the Toolkit and translating it into a suitable digital format format.

## 3.1. Living Lab Bus – Developer Portal

As mentioned in Chapter 1, Living Lab Bus provides a platform that focuses on empowering developers to create new digital services for public bus transportation.

Platform revolves around providing developers a number of hardware and software solution such as LLB On-Board Technical Environment, that consists of 3 busses supplemented with various sensors and public displays, Developer Portal and data processing infrastructure. Figure 3.1 shows the scheme of this environment.

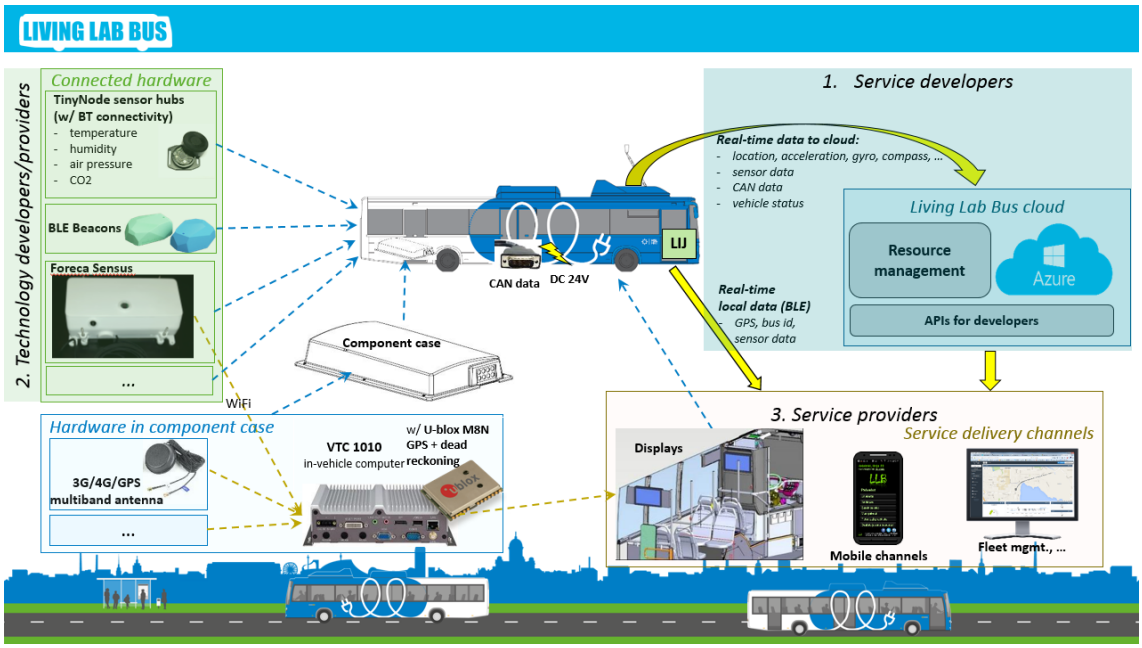



***Figure 3.1**. LLB On-Board Technical Environment scheme [47].*

Developer Portal [17] (Figure 3.2) provides an access to several APIs that can access bus sensor data, retrieved from LLB fleet of electric buses. RESTful API serves as a major tool for fetching sensor data in real-time and is mostly used in applications. Blob data API offers an access to a historical data, retrieved by every second within 24

hours and accessed via downloadable blob-files for each day. MQTT interface delivers real-time sensor data in a “provider-subscriber” manner.

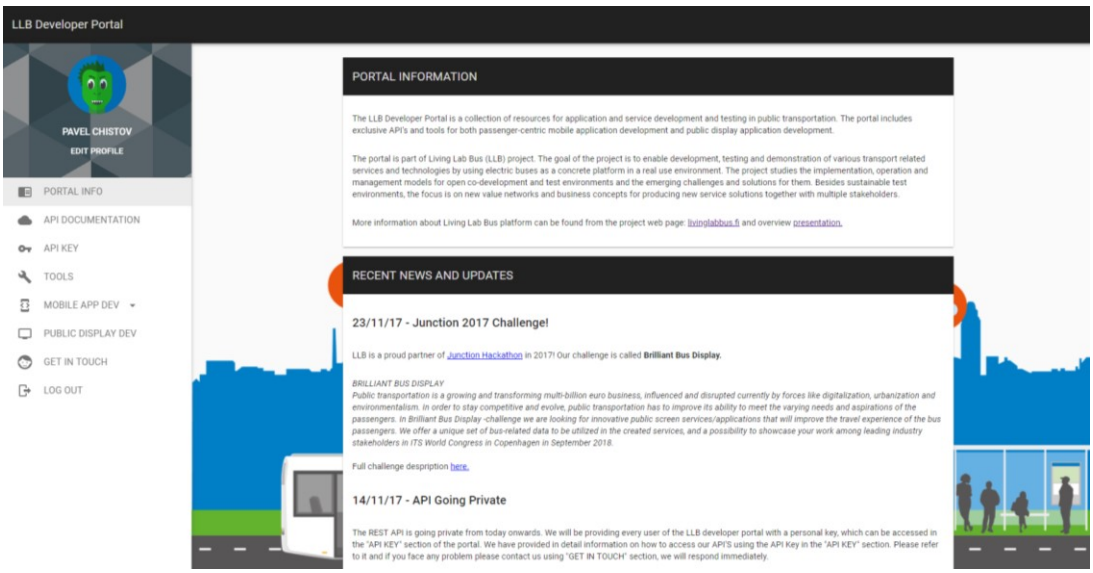



***Figure 3.2**. LLB Developer Portal homepage [17].*

Among other things, “Oma Kokoelma” (or “Own collection”) [57], serves as a publicly available hub for created applications. This service also plays demonstrative role (Figure 3.3) as it contains actual examples of how platform can be utilized for bus service development.

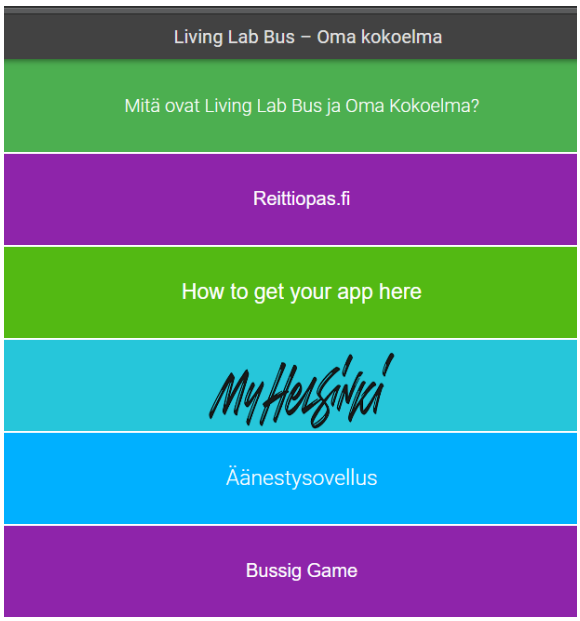



***Figure 3.3**. “Oma Kokoelma” (“own collection”) page showcasing the applications developed by using LLB platform [57].*

## 3.2. Bus Travel Experience Toolkit

Living Lab Bus also introduced Bus Travel Experience Toolkit as a set of ideation materials and tools to inspire and support software developers. Toolkit serves the purpose of providing a holistic view of bus travel experience by using them during ideation sessions.

Toolkit consists of 4 distinctive inspiration materials: Context Cards, Travel Experience Model, Passenger Journey Map and Passenger Personas.

***Context Cards*** (Figure 3.4) are used to support idea generation and serve as a context-specific and thematic cards. The usage of them is similar to PLEX cards (visualization and communication of ideas) and it is mostly happen during brainstorming sessions. Cards are presented in the amount of 10 and touch the subjects of themes formulated by Hildén et al. during their passenger studies: *ecological values, informative communication, entertaining activities, atmosphere of relaxation, premium experience, personality of driver, utilization of sensor data, commercial services and economical thinking*.

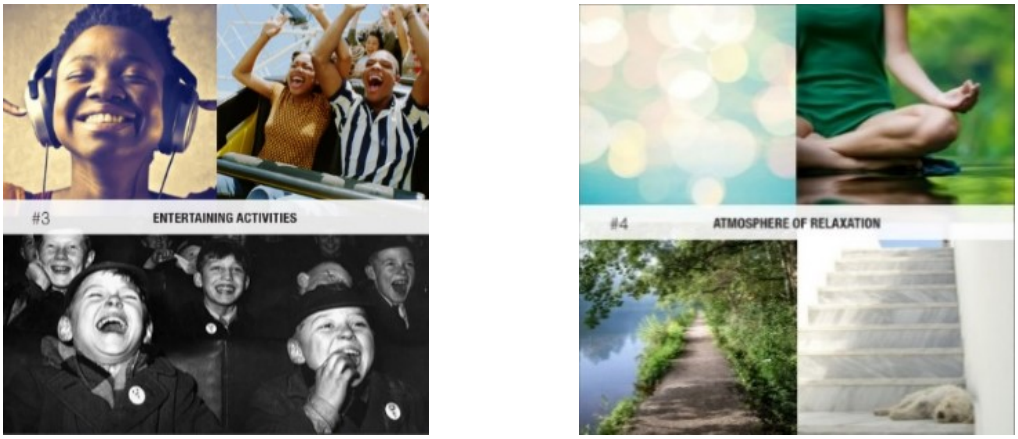



***Figure 3.4****. Examples of Context Cards, describing two different high level concepts within the bus travel experience – entertaining activities and atmosphere of relaxation [39].*

***Passenger Personas*** represent several passenger archetypes that are based on the insights of the Tampere and Helsinki pedestrians. Each persona is formed around specific bus travel habits and mobile device usage during the trip that are common for a particular archetype. Among other things, it also includes age and occupation. Five personas in total, each of them demonstrates a specific passenger type typical for Helsinki and Tampere urban areas. The importance of these personas is to provide enough passenger-related data and to use them when establishing the vision of some

bus-related project and its target audience. List of personas includes: ***Edward Enjoyer***, an elderly archetype that prefers social interactions with the passengers during the trip, ***Rachel Relaxed***, a middle-age archetype that considers daily bus trips as her personal quality time, ***Olivia Off-line***, another middle-age persona that values cleanliness of bus and silence during the trip, ***Isac Isolation*** (Figure 3.5), a student persona that isolates himself from other passengers during the trip and ***Emma Efficient***, a student archetype that choses to spend time on her tasks while traveling on the bus.


***Figure 3.5****. Example of Passenger's persona, describing Isac Isolation, a student archetype that prefers to interact with his mobile device rather that with the rest of the passengers [39].*

***Bus Travel Experience Model*** (Figure 3.6) is another inspiration tool that generalizes understanding of bus related context. It maps and visualizes knowledge and delivers holistic perspective on bus travel experience including actual users, various types of contexts and infrastructure. Each of the context contained a set of subthemes that serve to detail a certain context.

Model also visually represents the relationship between various digital services (planners, entertainment services, social media and other types) that passenger uses while using bus transportation or its services. It highlights various moods and motivations of the passenger specifically within the context of the public transportation.

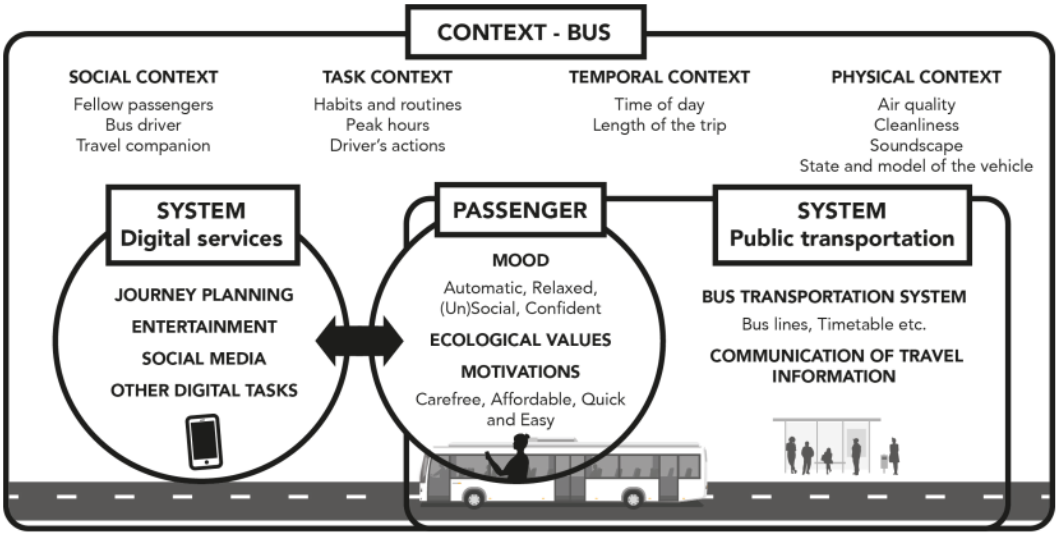



***Figure 3.6**. Travel Experience model [39].*

***Passenger Journey Map*** (Figure 3.7) serves similar purpose as experience journey map. In context of Toolkit, Passenger Journey Map breaks down typical bus travel situation or general bus context into set of sequential actions done by a passenger. These actions represent the touchpoint between the system (bus) and the user (passenger) and lists important outcomes of that interaction at given moment.


***Figure 3.7**. Passenger Journey Map [39].*

# 4. RESEARCH PROCESS

This chapter describes the research process of this thesis work, including schedule of each of the conducted studies and methods used.

## 4.1. Research schedule

Actual thesis work was divided into four major phases (as seen on the Figure 4.1) in the span of second half of the 2018 and beginning 2019.

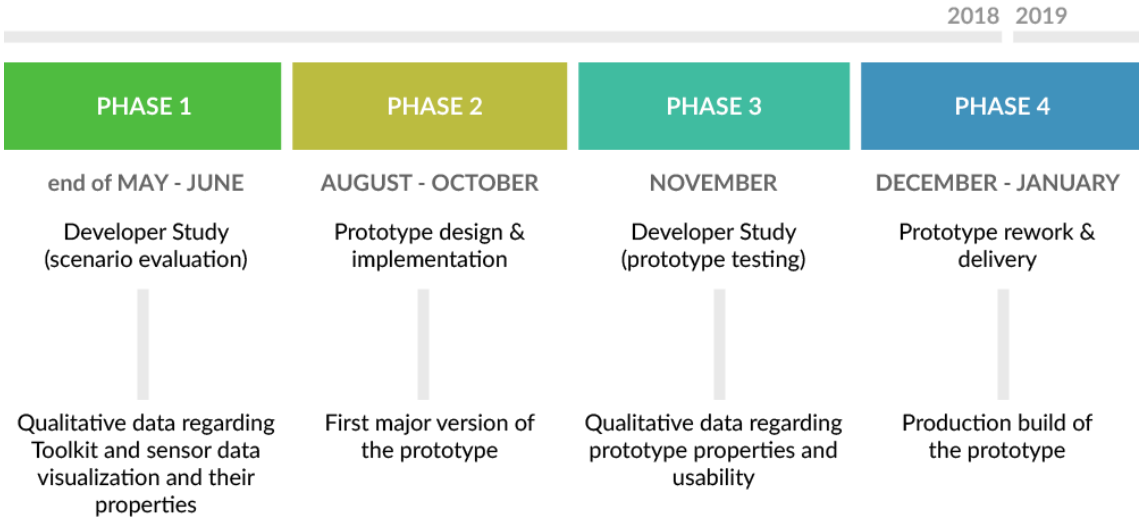



***Figure 4.1**. Phases of the thesis work and expected outcomes of each of the phases.*

During **first phase** a series of scenario evaluation sessions was conducted with software developers. Expected outcome was to gather qualitative data and insights regarding format and usage of the Bus Travel Experience Toolkit and sensor data visualizations. This phase was focused on answering to the first and partial answering to the second research questions. Phase lasted for five weeks starting from end of May 2018.

**Phase two** was the first practical part of the thesis work. It included design process and implementation of the first tangible version of the prototype that contains both Toolkit and sensor data visualizations. This phase targeted to answer to the second research question and explore the solution space of the third research question. Phase was started in August 2018 and lasted until the end of October 2018.

Testing sessions with software developers took place during **third phase**. That phase was majorly focused on answering the third research question. Phase took the entirety of November 2018.

The **fourth phase** was the second practical part of the thesis work. It implied to apply the results of the previous results and improve the prototype and preparing it for the delivery. Delivery took form of a making a production-ready build of the prototype, making it available for integration. This phase was the final answer to the third research question and took entire December 2018 and January 2019.

## 4.2. Research methods

Figure 4.2 demonstrates overview of the methods that were used during each of the phases of thesis work.

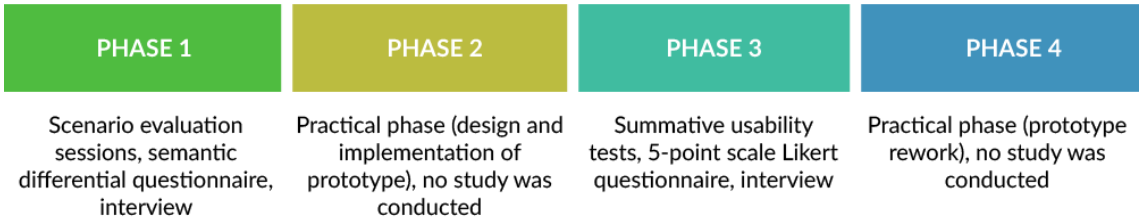



***Figure 4.2**. Methods used for each of the phases*

### 4.2.1. Qualitative methods of data gathering

Due to the nature of the thesis work as a qualitative one, qualitative methods of gathering the necessary data serve as a major contributors to the thesis work.

*Scenario evaluation* [1] is a technique that revolves around user scenarios and their evaluation by invited participants. User scenarios contain a narrative explaining user's motivation and actions while using some service or a product. Scenario are used to have a deep look at what may drive user to find and/or use said product. Evaluation process includes scenario reading and discussion of its major points and interaction descriptions and whether they can be considered feasible and sensible.

*Interviews* were part of both studies in first and third phases. Short 5-10 minutes semi-structured interviews were conducted after scenario readings during first phase and upon completing all the tasks and filling post-testing questionnaire during usability tests in the third phase.

*Assessment* or *summative usability test* [62] was introduced in this research during third phase. Assessment test methodology generally focuses on having a relatively

small scale and on discovering potential problems or evidence of such problems with the user interface. This test is often being conducted in the middle stages of product development when most of the general structure and principles of product design are set. During these tests, moderators have a reasonably small amount of interactions with the participants. Participants are meant to actually perform general tasks by using a prototype of the product that was presented to them rather than commenting on them and thus, may not be asked to think aloud. Think aloud protocol [46] is used in usability tests as a way of gathering raw data from participants. In general, participants are asked to audibly comment on anything that they do while performing specific tasks. They may describe not only performed actions, but also how they feel and practically anything that they wish to say in regard to the properties of tested system.

Additionally, aside from performance artefacts and qualitative data, a lot of quantitative data is collected during the test.

### 4.2.2. Quantitative methods of data gathering

Speaking of quantitative methods, a set of various questionnaires were used during the thesis work.

*Background questionnaires* were part of the first and third phases and generally served to gather basic demographic data about software developers that participated the studies during those phases.

*Semantic differential* pairs provided quantitative data regarding some of the properties of the Toolkit and sensor data visualizations during first phase of the thesis work. General purpose of this questionnaire is to establish a rating system (scaling from “bad” to “good” or equivalently opposite ratings) that would allow participant to evaluate a specific attribute of the Toolkit and sensor data visualization design presented in the scenarios. Each of the pair had its own context of the ratings, allowing to collect more complex feedback from participants.

Basic 5-point scale Likert questionnaire was used during usability tests to capture initial reaction on certain properties of the prototype during third phase. Scale for each of the statements was from “strongly disagree” (represented with numeric value of 1) to “strongly agree” (represented with number 5), while middle value was meant for neutral response.

### 4.2.3. Methods of analysis

Analysis of the qualitative data from first phase interviews and participants' commentary started with transcription of the audio recordings and session notes and highlighting the quotes from participants. Further analysis involved seeking commonalities between raised concerns of participants as well as some isolated and unique cases and experiences. All of the data was put in a digital format in Google Sheets service and divided into four different categories for each of the participant. Categories included notes and quotes related to first scenario, second scenario, current version of the Toolkit and sensor data visualizations, developers' sources of inspiration and ideation. Findings from third phase interviews was analysed similarly by categorizing and compiling lists of common themes that may occur among insights and notes.

Quantitative data was analysed by calculating mean and standard deviation values for each of the statements in the Likert questionnaire from the third phase across all participants. Mean value would give a more simpler view of the data from multiple participants and standard deviation would demonstrate how much this data deviates from its mean value.

Data gathered from semantic differential questionnaire was also analysed by calculating ´mean values and presenting in a visual format to demonstrate data spread across all of the statements.

# 5. DEVELOPER STUDY – SCENARIO EVALUATION

This chapter describes the first phase of thesis work, a series of scenario evaluation sessions. Presented scenarios contain two different stories involving two distinct characters that use LLB services and Bus Travel Experience Toolkit for the first time. The study involved ten software developers in total, it was started in the end of May 2018 and lasted for five weeks.

General purpose of the scenarios was to see if the flow and usage of the proposed variants of Toolkit and sensor visualization structure, format and actual content could be considered feasible, beneficial and usable.

This chapter describes the procedure, its details and participants and results of this study.

## 5.1. Participants

The recruitment was mostly performed via personal contact with potential participants and sharing Doodle form with a list of available time slots. The general requirement for selection was having a background in programming and/or software engineering. Table 5.1. presents all 10 participants of the study and their background information retrieved from background questionnaires. Average age was 28 years with 25 and 34 years for youngest and the oldest respectively.

***Table 5.1**. Scenario evaluation participants.*

| ID | Age | Gender | Occupancy | Participation on start-ups | Participation on open source projects | Awareness about LLB |
|---|---|---|---|---|---|---|
| P1 | 28 | Male | Software developer/student-developer | No | No | Heard of it, but never used it or looked at it (courses and workshops) |
| P2 | 26 | Male | Software developer/student-developer | Yes | No | No |
| P3 | 29 | Male | Other (machine learning engineer) | No | No | No |
| P4 | 33 | Male | Software developer/student-developer | Yes (Taskulu) | No | No |
| P5 | 25 | Male | Software developer/student-developer | No | Yes (Open SSL) | Heard of it, but never used it or looked at it (lab presentations) |
| P6 | 26 | Male | Software developer/student-developer | No | Yes | Heard of it, but never used it or looked at it |
| P7 | 34 | Female | Other (junior test engineer) | Yes (Toyme Lab Oy) | Yes (fiware - Tampere smart city | Heard of it, but never used it or looked at it |
| P8 | 27 | Female | Software developer/student-developer | Yes (wirepas oy) | No | No |
| P9 | 30 | Male | Software developer/student-developer | No | No | No |
| P10 | 26 | Male | Software developer/student-developer | No | No | No |

## 5.3. Procedure and materials

Sessions took place in Tampere University (Hervanta campus) and its premises during the last week of May 2018 and entirety of June 2018. Each participant was introduced to the study and asked to sign consent form and fill background questionnaire. ***Consent form*** (Appendix G) described the purpose and procedure of the study, participant's rights and staff obligation to process their data anonymously within Living Lab Bus project. ***Background questionnaire*** (Appendix G) was related to their age,

gender, current occupation, previous experience in start-ups and open source projects and awareness about Living Lab Bus project.

After that, participants were handed with scenarios. ***Scenarios*** (Appendices A and B) were the essential part of the study. Each scenario involves its own main character that uses Developer Portal and Toolkit combined together. Main difference between scenarios is actual interactions with the mentioned tools. In order to visualize it, each scenario was additionally supplemented with a set *wireframes*. Said wireframes were also meant to visually demonstrate interconnection between tools in the Toolkit and sensor data visualizations. Each wireframe page was printed out and referred in the scenarios texts as “figures”. Wireframes and scenarios are presented and explained in the following subchapters.

### 5.3.1. “Inexperienced developer” scenario and wireframes

First scenario – “Inexperienced developer” (Appendix A) – introduces Jussi, a junior software developer working in a start-up company. He lacks some bus related knowledge that is required for his software project at work. Thus, he is in active search for a web resource that could help him to gain that knowledge about bus technical environment and bus context in general. He stumbles upon a Developer portal that offers interactive Bus Travel Experience Toolkit and Living Lab Bus API. He checks up both of them and ends up on Olivia Off-line persona page that contains references to other tools and sensor data visualizations.

Wireframe set for this scenario demonstrates a clear separation of developer (API and bus application templates) and designer (Toolkit) tools. Flowchart of this set is available on Figure 5.1.

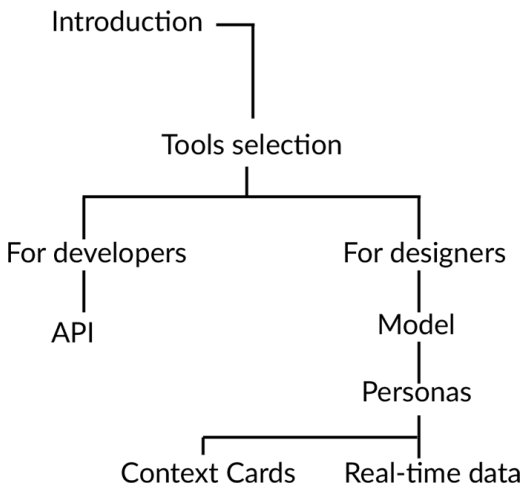
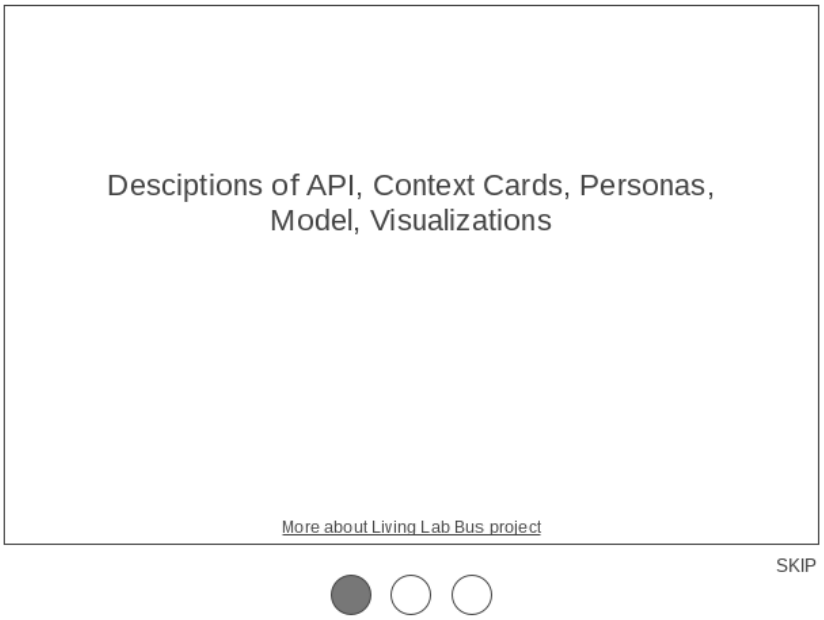



***Figure 5.1**. Flowchart of the wireframes for "Inexperienced developer" scenario.*

Starting from introduction slide (Figure 5.2, top), Jussi skips it straight to the tools selection slide (Figure 5.2, bottom), where he can select between developer and designer tools.



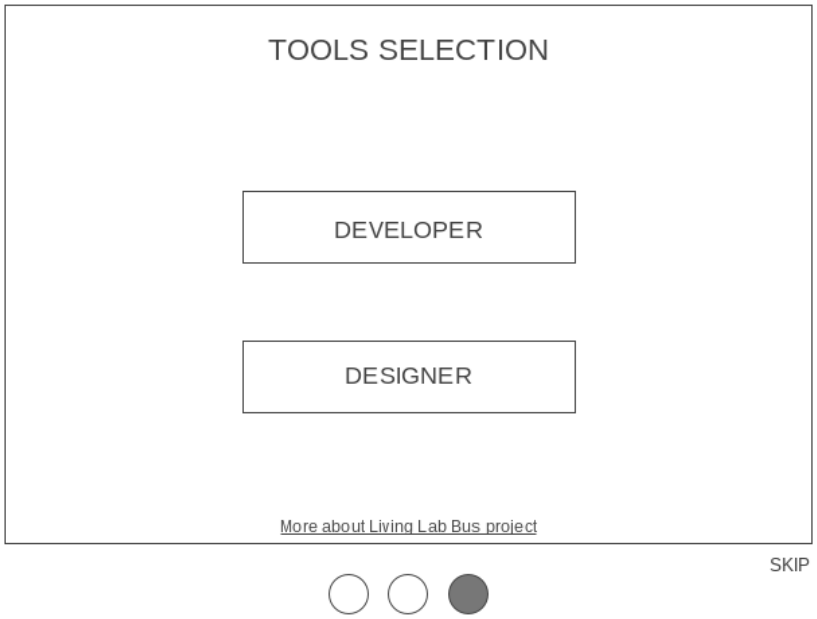



***Figure 5.2**. Wireframes of introductory (top) and tools selection (bottom) slides.*

After exploring developer tools first (Figure 5.3, top), Jussi swtiches to designer tools (Figure 5.3, bottom) page. That page introduces Toolkit to Jussi and suggests to check Travel Experience model first as an overview of the bus context.

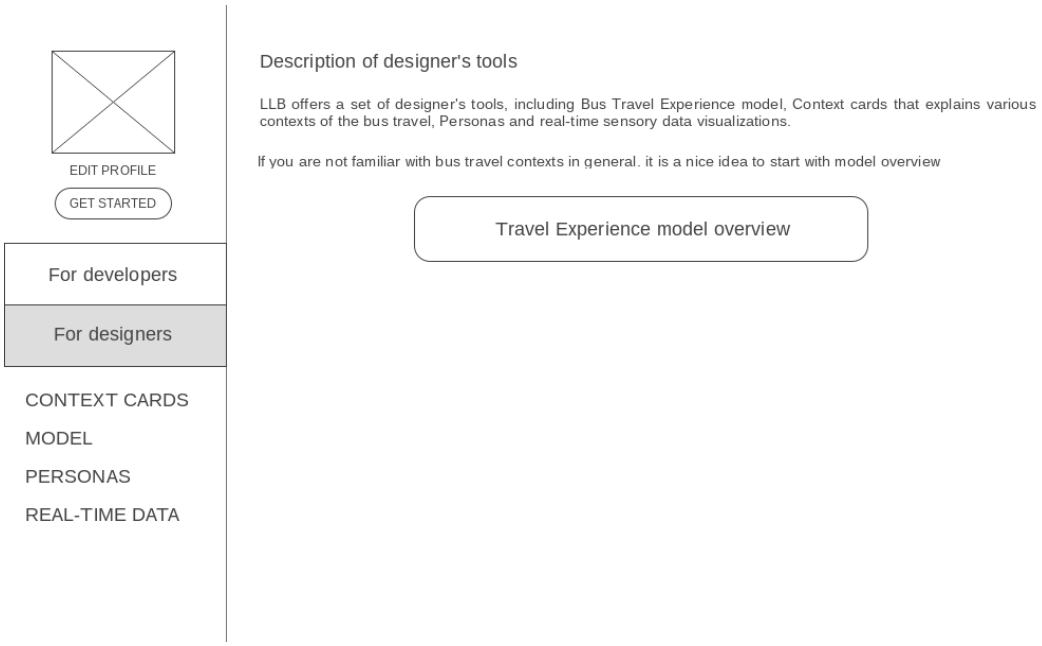
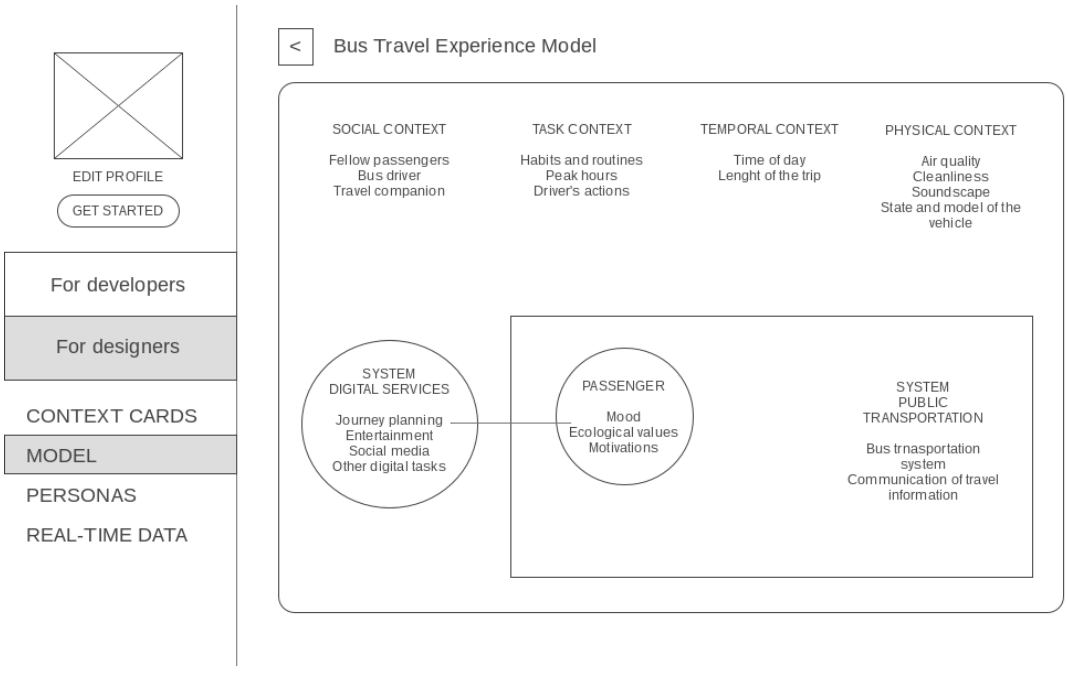



***Figure 5.3**. Wireframes of the developer's (top) and designer's (bottom) introduction pages.*

Travel Experience Model page (Figure 5.4) imitates paper original and allows to view each of contexts (Figure 5.4, middle) separately. Each of the subthemes included in the context is explorable on its own and supplemented with Explore button. In that case, Jussi selects Physical Context and decides to explore Air Quality subtheme. Upon clicking on Explore button, Jussi reaches Olivia Off-line persona page (Figure 5.4, bottom) that includes all Olivia's data as well as related Context Card.



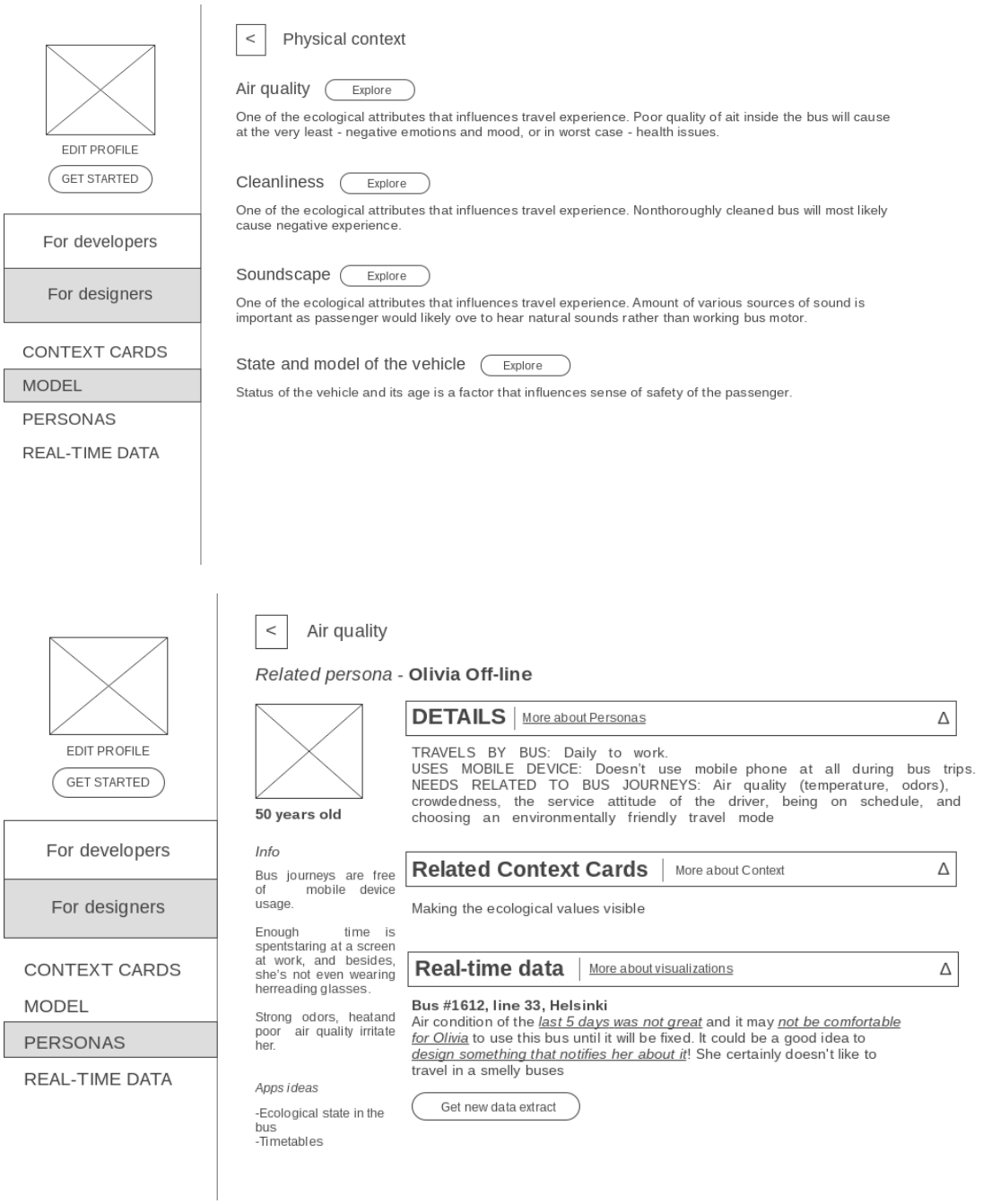



***Figure 5.4.*** *Wireframes of pages, representing basic structure of Travel Experience Model and its content. Includes Travel Experience Model page (top), Physical Context page (middle) and Air Quality subtheme page (bottom).*

Sensor data visualizations are presented in the same page in a form of suggestive flavour text hypothetically based on accumulated and analysed sensor data from LLB buses (Figure 5.5). Jussi is able to get a new suggestion by pressing “Get new data extract” button.

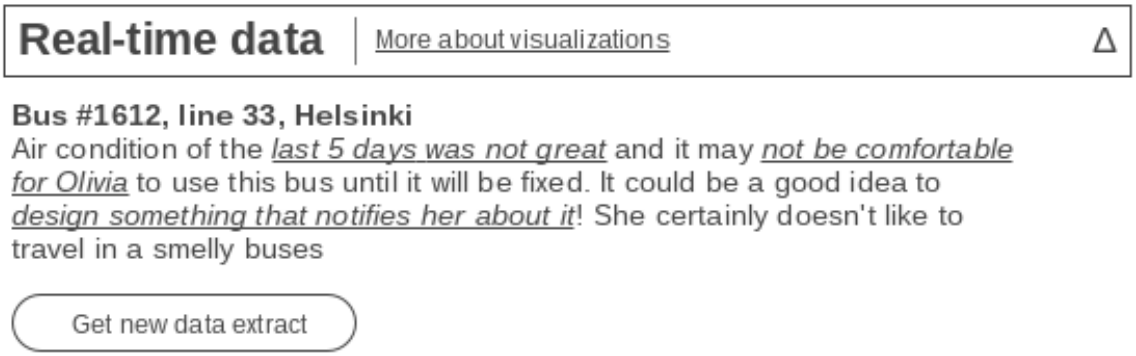



***Figure 5.5**. Sensor data visualization are presented in a form of suggestive text, randomly generated from existing sensor data.*

### 5.3.2. "Limited designer" scenario and wireframes

In the second scenario, "Limited designer" (Appendix B), Heimo, a main character, has an idea for a public bus transportation service. He needs some basic validation of his idea without conducting a full-fledged research. He finds that opportunity by checking out Developer Portal and Toolkit via advertisement inside the bus. He goes through most of the tools and eventually ends up on Isac Isolation persona page that similarly contains references to other tools and sensor data visualizations.

Wireframes for this scenario are focused on dividing actual offerings of the Developer Portal and the Toolkit directly. Flowchart for this wireframes set is presented on Figure 5.6.

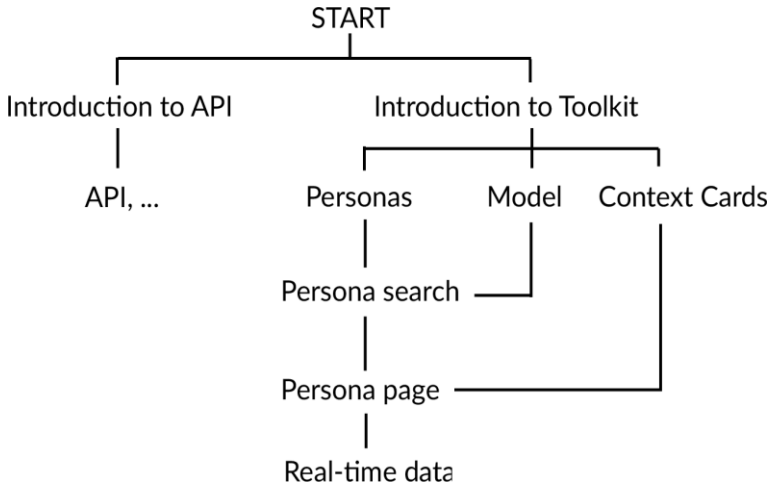
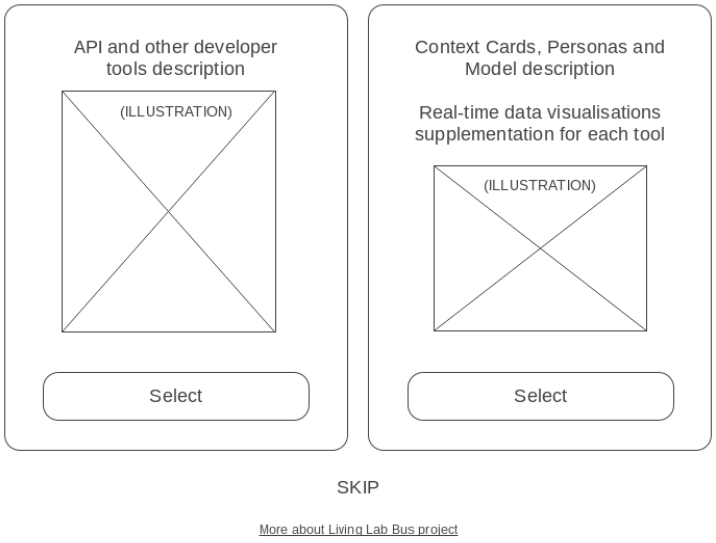
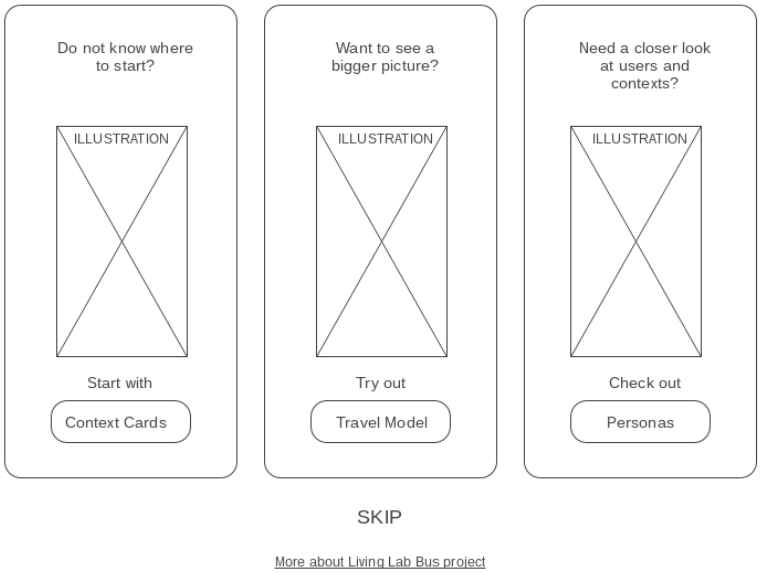



***Figure 5.6**. Flowchart of the wireframes for the "Limited designer" scenario.*

Heimo starts with a choice between API with other developer tools and Toolkit (Figure 5.7, first). Upon selection of the Toolkit, another choice is given to him – he needs to select between Context Cards, Personas or Travel Experience Model (Figure 5.7, second). Choosing Personas leads Heimo to a separate page that presents search

functionality for the Personas. This functionality is based on the selection of the contexts from Travel Experience Model and search for relevant Personas. In this example, by selecting “bus occupancy” and “noise level”, page finds Isac Isolation persona (Figure 5.7, third) and displays it to Heimo. Isac’s page (Figure 5.7, fourth) includes data about Isac himself, links to the related contexts in the Travel Experience Model, Context Cards and sensor data. Sensor data visualizations (Figure 5.8) are presented in a similar to the “Inexperienced developer” scenario manner (text based on pre-processed sensor data) and supplemented with a city map.



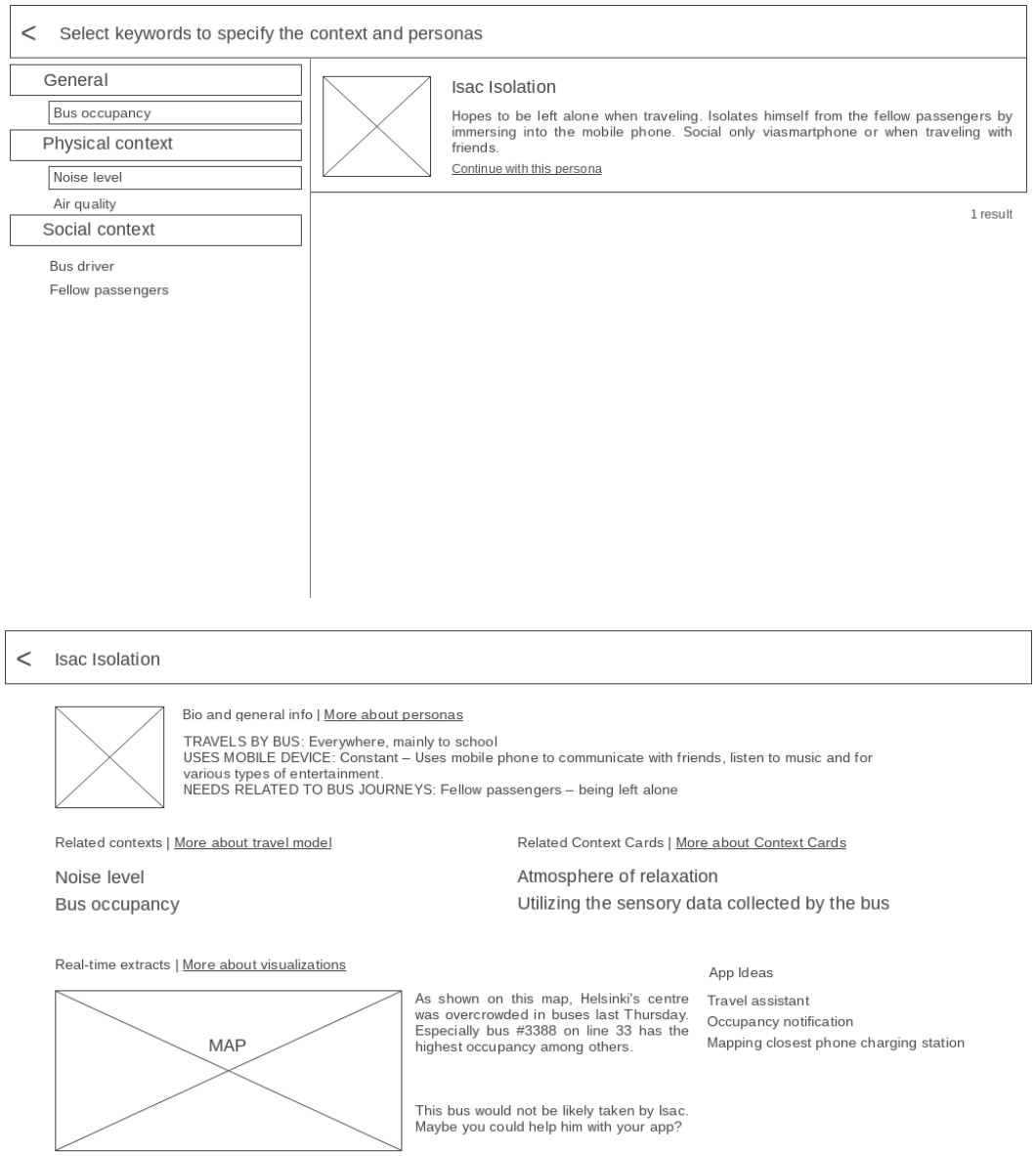



***Figure 5.7**. Wireframes of introduction slide (first), Toolkit offering selection (second), Persona search (third) and Persona page (fourth).*

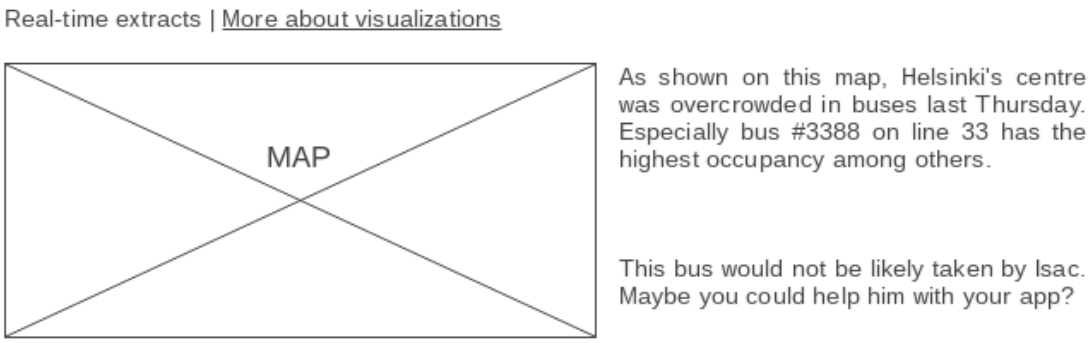



***Figure 5.8**. Sensor data visualization in the second set of wireframes is presented in a form of another suggestive text.*

After each scenario reading and getting familiar with the wireframes, participants were handed with a ***post-reading questionnaire*** (Appendix F). Said questionnaire was meant to capture the initial impressions of presented narratives. It contained several statements mostly related to the structure of the scenario and proposed wireframes. Short interviews were conducted after that regarding scenarios and their details. ***Interview questions*** (Appendix C) were threefold. First batch of questions were primarily focused on scenario and its consistency, realistic nature, best and worst parts of it, introduction of toolkit and sensor data. Second part was in relation to what could be the potential improvement of the toolkit. Last batch was about participants sources of inspiration (tools, situations, previous experiences, ...) and experience with other design tools and guidelines.

After both scenarios being read, participants were finally handed with currently available Bus Travel Experience Toolkit with follow-up interview about their usage and improvement. ***Toolkit*** included Context Cards, Bus Passenger Personas, Travel Experience Model and Passenger Journey Map and was handed to participants to check out and form an opinion on them. Toolkit materials were used in a paper format.

## 5.4. Findings

General response to the scenarios and wireframes were quite positive, but not without concerns. First scenario (“Inexperienced developer”) and its wireframes were considered harder to get through than the text of “Limited designer” one. Its story was perceived to be more complicated and participants also wanted to see more information of how Jussi could use LLB API. The pace of Jussi exploring the Developer Portal was also noted to be slower that it is usually happen in real life. Also, P3 mentioned that Jussi would probably check out the Toolkit materials and other offerings during his working hours rather than his own personal time as assumed in the scenario.

Second scenario was more streamlined, more fast-paced and more convincing to the participants. P7 even mentioned its the similarity with the real life situation she experienced. She recalled checking some digital service after seeing advertisement in the bus - similar to Heimo in the second scenario.

Post-reading questionnaires results (Figures 5.9 and 5.10) showed that proposed toolkit structure and means of its application can be considered realistic and these situations are likely to happen.

Developers were also quite positive regarding the materials and their content, also considering that almost none of them had a knowledge and/or experience with any UX related tools beforehand. Similar reaction was received in regard of sensor data visualization that were considered both useful and simple to understand. Proposed layout and navigation of the potential was also considered easy to follow and clear enough for potential use. But despite positive reaction, there were some concerns and interviews revealed several major points of developers' struggles with the Toolkit.

**Scenario 1 – post-reading questionnaire mean values**

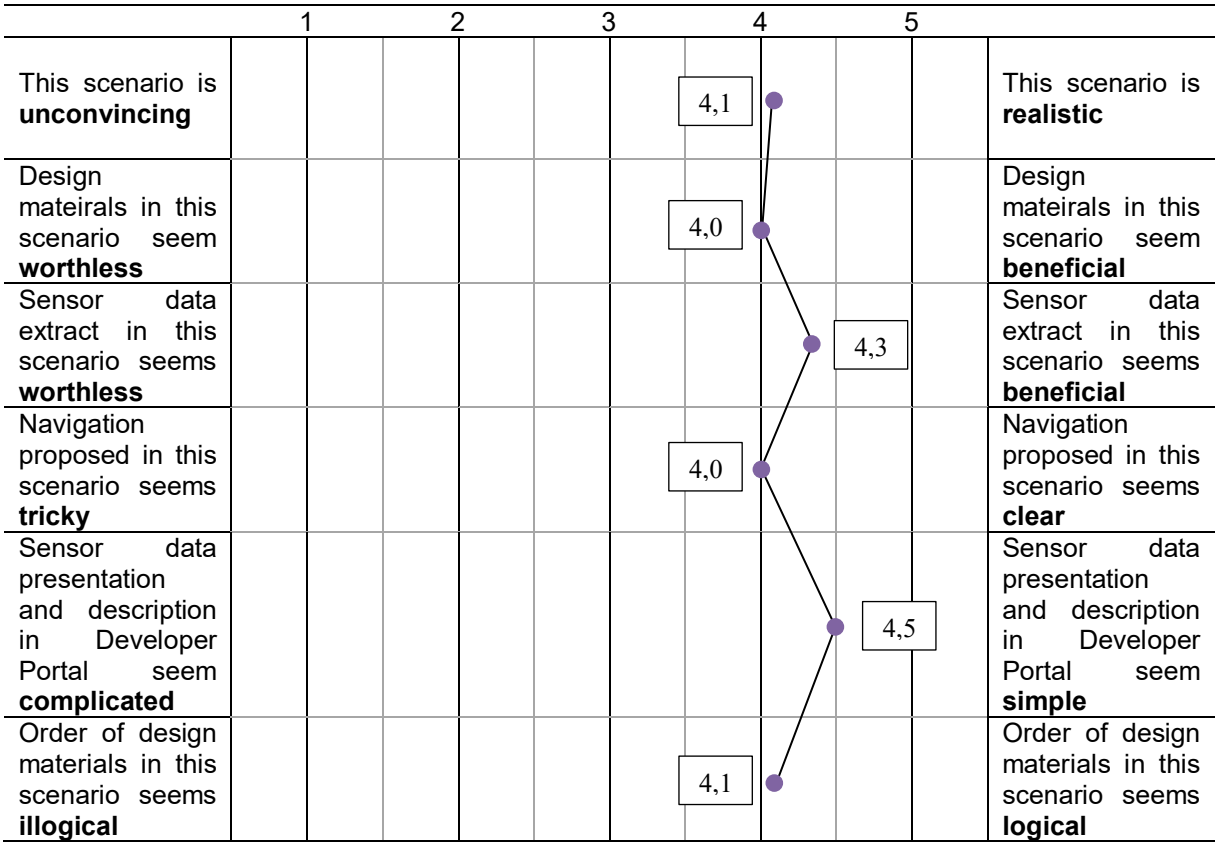



***Figure 5.9**. Post-reading questionnaires mean values for the "Inexperienced developer" scenario (N=10).*

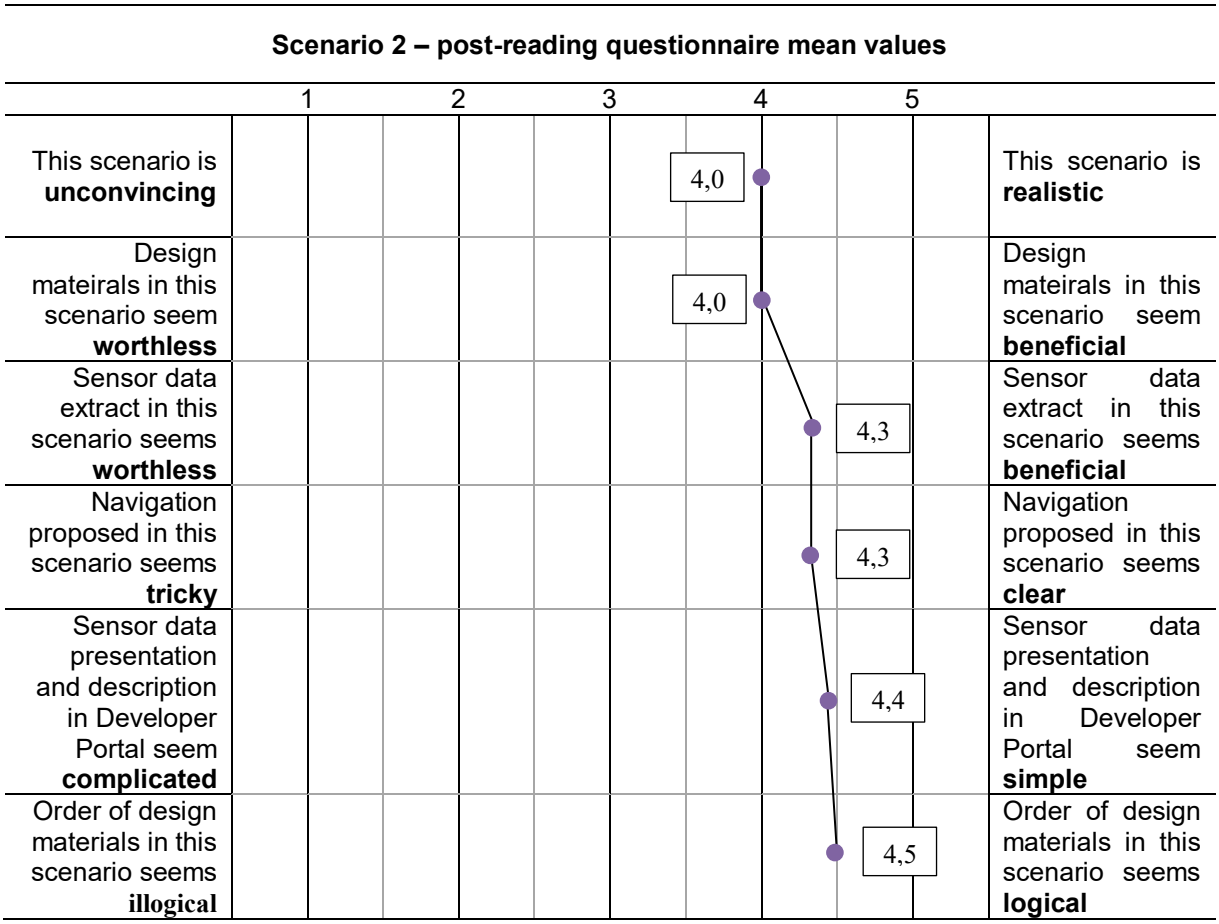



***Figure 5.10**. Post-reading questionnaires mean values for the "Limited designer" scenario (N=10).*

**Developer's experience, practicalities and expectations**

The qualitative findings revealed specifics of the process of ideation participants described. Most of the developers stated that they never used any sort of design or style guidelines and prefer to seek for existing solutions. P8 mentioned usage of material design guidelines and EU regulations and guidelines related to accessibility for impaired and disabled people.

Most of them stated that having some problem to solve is enough to drive them to create some solution. P1 stated: "*Needs. People need something, some solution for their needs*". "*There is always a need. Not even own need. Always a friend or person saying that something does not work the way they want it to be*." (P10). Other participant (P7) stated that the competence plays major role: "*What makes people creative - experience in the subject and ability of seeing the problem in environment/context*". Same participant also mentioned her approach to ideation process as an attempt to find some correlation between her work and her major studies: "*I like my major, I like my workplace, but I don't like my job, so I try to find*

*something related to my major and try to announce it like - here you can visualize data this way...*".

There was additional concern about overall application of the Toolkit. For example, three participants described their desire to see more information about LLB's API or see some examples or code snippets within the Toolkit, despite the intent of the Toolkit to provide useful information on its own. It was mentioned on top of aforementioned general desire to see Jussi actually using the API. P4 mentioned that without API, provided data may not be sufficient: *"... without practical example of API and code I will probably go outside the LLB and see if other platforms would offer to do something similar*".

The cause of it was seemingly due to the design in scenarios being based entirely within the possible structure of the Developer Portal that provides API endpoint. Additionally, there were mentions of the API and distinct separation of portal's offerings for developers and designers. P3 approved the separation between Developer and Designers sections in the first set of wireframes: "*Separation of designer and developer is good.*". At the same time, same participant did not like similar separation between offerings and presenting the choice between them upfront in the second one: "*Do not force the decision making.*". Other participant (P10) mentioned that forcing the choice in the first scenario may lead to confusion, e.g. in case user does not understand the meaning of developer tools proposed in wireframes: "*If now I click on Developer - am I missing something? What if a portal designer has different opinion of what goes to developers and designers section and what if categories don't match? You can go back, of course, but would be nice to have a key notes about what goes to what category (with text at least). Otherwise it is leap of faith*.". Another participant didn't approve the separation at all, wishing to have entire content available in one place.

Another question was raised in regard of novelty or familiarity of the tools. At least two participants expressed their desire of have some sort of tutorial or some structure that would explain how to use the Toolkit.

**Lack of available research data**

In case of some participants, this concern initially led to underestimation of the content of the toolkit and it took some explanation to convince them that this is not a made-up data: *"I hope you are not making this up"* (P2). Data mapping was also the question raised by P4, e.g. how many real passengers match a particular persona.

P9 imposed an interest on the freshness of the data and proposed to add some functionality to the portal that developer could use to contribute to or share the related research results of his own, adding to the existing data.

**Terminology and format of the toolkit**

Terminology also contributed to the initial confusion due to the fact that most of the participants never used any UX related design or inspiration materials in the past. For example, term “persona” was causing some difficulty in understanding among some developers, but when described as “archetypes” participants immediately managed to get the general idea of the tool. In case of one participant, his lack of experience with card-based ideation tools and his response caused some questions towards the idea of the Context Cards’ fundamentals and their general purpose.

Response to Context Cards across all participants was the most positive. The only given concern was amount of the cards and what is the right amount is needed to effectively use them: “*I am not sure how many cards are needed to start generating ideas*” (P2).

Passenger Journey Map also got mostly positive receptance: “*Useful to communicate with designers.*” (P4). Some participants mentioned the lack of variety of situations presented, but nevertheless for the most part, it contained sufficient information to start generating ideas: “*Different situations do not really matter, it already gives a pretty good idea and context*.” (P2). Other participant (P9), who had some prior experience with journey maps, was looking for a more traditional looking customer journey map, e.g. with a breakdown to emotion, task and other elements at each of the touchpoints

Travel Experience Model was one of the tools that got mixed reactions. Most of the participants did not have strong opinion on it, but some of them gave specific comments. For example, in one case (P4) model was considered to be useful for communication within some development team while also mentioning that it could be supplemented with some references to LLB API for each of the contexts and themes. In other case, participant reinforced positive reaction regarding contexts: “*Top row of the model is most important for people concerned about these contexts when they are using an app*” (P6). On the opposite side, two participants (P7 and P8) were not sure how to interpret the lower part of the model related to the relationship between passenger, digital services and public bus transportation. P3 did not manage to understand the purpose of the model at all.

Passenger Personas caused most of the questioning pointed towards the Toolkit. One of its major perceived disadvantages was lack of research data that could describe

what data was behind each of the personas. In case one of the participants (P2), he even assumed that personas' content was just an assumption and it also inflicted underestimation towards entire Toolkit - as was mentioned above. Other participant was intrigued how much personas could overlap with each other: "*How personas map to actual people and how often they overlap? Is Rachael Relaxed is always like that or during working hours? Maybe outside working hours she is Emma Efficient*?" (P4). Other concern was raised about amount of content available by two participants: "*Five or six personas is not very enough, to be more realistic it needs to be 10-15 as you work with different age groups, genders, nationalities*." (P3). Quote: "*Are you looking for more archetypes? I use bus so much, I can see literally see every person categorizing in any of these*" (P5).

**Sensor data visualizations feedback**

Presented the description of the bus sensor data visualization has generated fairly diverse range of opinions. All participants suggested some basic data visualization techniques to reveal data of a technical kind rather than a suggestive text. For example, P4, P5 and P6 suggested to add heat maps, timetables, raw parameter values and other generic forms of visualizations. P4 also thought of a proper data analysis tool with possible sensor parameter correlation analysis and different views of the same data for different contexts. At least two participants (P8 and P5) expected to see diagrams and raw data in the first place, one even stated that he wants to conduct some analysis on his own instead of being offered with suggestive text.

One participant (P3) thought of proposed idea as an attempt to form a some patterns from available data. P4 stated that presented example is an effective example what can be done with the sensor data.

**Conclusion of the scenario evaluation sessions**

This study revealed a number of questions that became the focus points for the first version of prototype, designed and implemented in the next phase. Lack of access to research data about Toolkit caused pretty significant impact on developers expectations as well as presence of direct ties to the API and Developer Portal. Terminology, general language and some elements of format of the Toolkit were another obstacles that influenced tools understandability and perceived familiarity. Feedback of sensor data visualization concept made it clear that developers expect more of a traditional approach to data representation.

# 6. PROTOTYPE DESIGN AND IMPLEMENTATION

This section describes the second phase of the thesis work – design and implementation of the first version of the Toolkit portal prototype based on the feedback received from previous study and basic wireframes that were created for scenario evaluation sessions.

## 6.1. Goals and user tasks

One of the main concerns that was considered during this phase of the work is a strong connection to the Developer Portal and how it set unnecessary expectations from the Toolkit the during previous phase of the study. Furthermore, given the intent to provide publicly open data regarding bus travel experience, there was a question of Toolkit availability. Therefore, first of the goals of this design was ensure user *reachability of the prototype*. This goal was considered achievable by developing the prototype and eventually integrating it to LLB infrastructure as a separate resource and not part of the Developer Portal as it would exclude authentication process that would block the content behind registration.

Second goal was to *introduce the interconnection between tools within the Toolkit*. This goal can be divided into several sub-goals:

- Make sure that user is aware about the entire toolkit offering by linking tools between each other. Additionally, there should be some learning element to the introduction of each of the materials and Toolkit in general.
- Make sure that the tools are supplemented with the real data and research materials describing the process of their design and creation.
- Make sure to have a sensible and understandable connection between tools and bus sensor data visualizations.

The third goal was to ensure that the *content and its structure are adapted for developers based on the feedback from developers regarding terminology and format of the tools.*

Table 6.1 explains general tasks that user will do in the future prototype. They are important as they represent reference points that will communicate design and flow.

***Table 6.1**. User tasks and their descriptions.*

| | User task | Question | Description | Action |
|---|---|---|---|---|
| **1** | Search for bus related researches results | "What if someone already solved this problem?" | Developer would like to find some research data for his bus related projects to check if there is already a solution for his problem | Find the relevant resource (prototype) and get familiar with it (introduction page) |
| **2** | Search for passenger data | "What kinds of passengers exist?" | Developer wishes to see what type of passengers are out there to specify project's target audience. | Find Passenger Personas |
| **3** | Search for context data | "What situation can happen during the bus trip?" | Developer wants to find some information about contexts of use and general understanding of what properties of bus travel are important to note | Find Bus Travel Experience Model |
| | | "What kind of situation or context I need to address with my project?" | | Find Context Cards |
| | | "Where and when exactly my project could be used?" | | Find Passenger Journey Map |
| **4** | Search for bus technical data | "What kind of hardware is inside the buses?" | Developers needs to know what technical data it is possible to use for the project implementation | Find bus sensor data visualizations |
| | | "What kind of bus sensors can I utilize for my project?" | | |

## 6.2. Implementation tools

Prototype was developed primarily with React.js library that was used for architecture and HTML and CSS Grid in particular for layout. React.js [60] is a popular JavaScript library that is used to build user interfaces and application for both web and mobile. It is also commonly used for creation of Single Page Applications (SPA) that render entire application on one HTML page and dynamically update its contents on demand that allows to avoid constant page reloads. Toolkit Portal took form a such SPA.

Node.js [54] run-time environment was used during implementation phase as well and served to execute Javascript code. Node package manager [55] served as a source of necessary basic packages for React.js application.

Google Geo API was also utilized to provide JavaScript-based map component for bus sensor data visualizations.

## 6.3. Design approach

### 6.3.1. General theme and layout

Overall theme was based around familiarity factor of the layout, so the design was inspired by programming documentation websites such as Redux framework website **Error! Reference source not found.** (Figure 6.1). General approach to the layout was t o have some resemblance with mentioned portals so it would hint the purpose of the portal from the first glance at it.

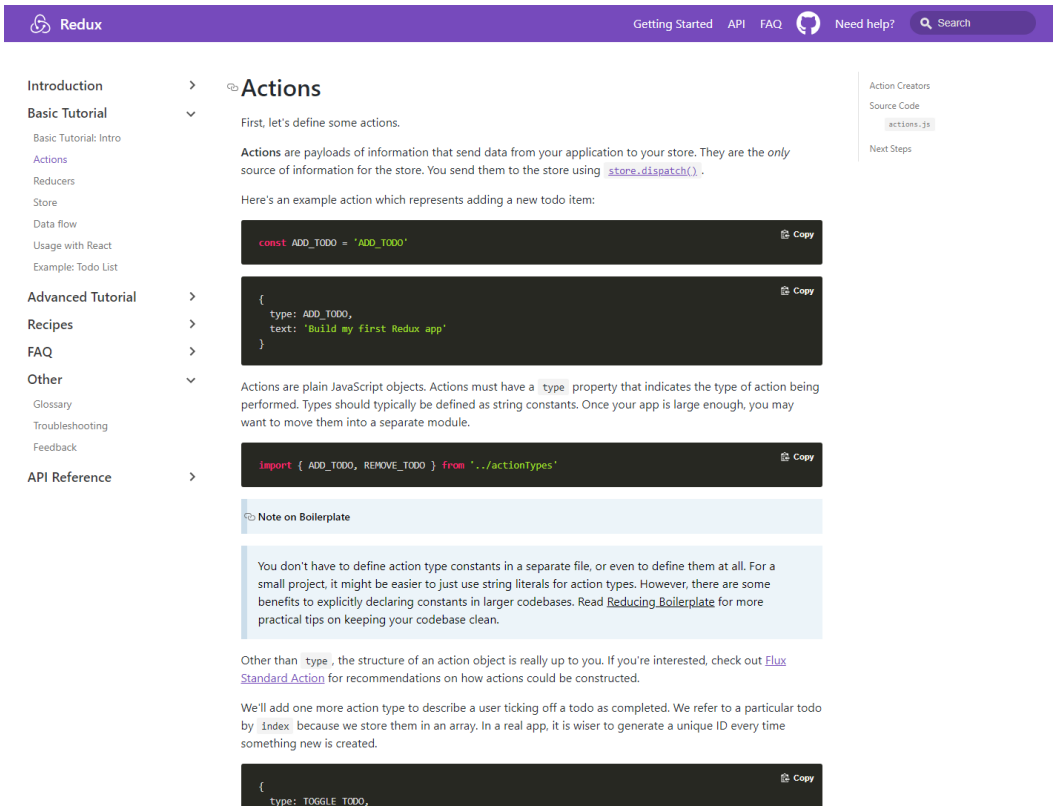



***Figure 6.1**. Redux framework website layout.*

Content limitations were also considered when designing an application. It was decided not to present the entirety of available Toolkit data, but only a fraction of some of its parts. For example, portal would be not supplemented with all 5 personas, but rather only two – Edward Enjoyer and Olivia Off-line. In case of Bus Travel Experience model, only Social and Physical contexts received their own pages that contain rich descriptions of their subthemes. The main purpose of such approach was to give an example of connections within toolkit without spending time on full implementation of the portal. Codebase and general structure of the prototype was going to change eventually based on the feedback from the next stage of the thesis work.

One of the main obstacles with the design was actual title of the portal. There was many suggestion regarding whether it should be called “LLB Design Toolkit Portal”, “Inspiration Portal” or “Inspiration Platform”. Eventually, it was decided to go with “Research Portal” to see how it would resemble.

### 6.3.2. Navigation and flow

Original flowchart (Figure 6.2) of the possible LLB infrastructure and prototype integration was proposed to set up a spot where prototype would take its place. Starting from Living Lab Bus project website, user would find the link to the prototype in the “Offerings” section. Developer Portal, project website and the prototype would be interconnected within proposed structure by linking to each other in relevant parts. For example, Prototype would have a “More about LLB” link to the LLB project website in case user would like to know more about the project. Somewhere in the Developer Portal, user would find a link to a passenger research content that would redirect user to the prototype.

Prototype itself would contain some API documentation and each material in the Toolkit have a connection to the relevant part of the API, e.g. physical context from the Bus Travel Experience model would link to the API output related to the physical parameters from sensors (air pressure, noise level, etc.).

Terminology would be different within the Toolkit and throughout the prototype to resemble more of a research portal. E.g. instead of Toolkit and Personas, portal would go with Analysis and Users respectively.

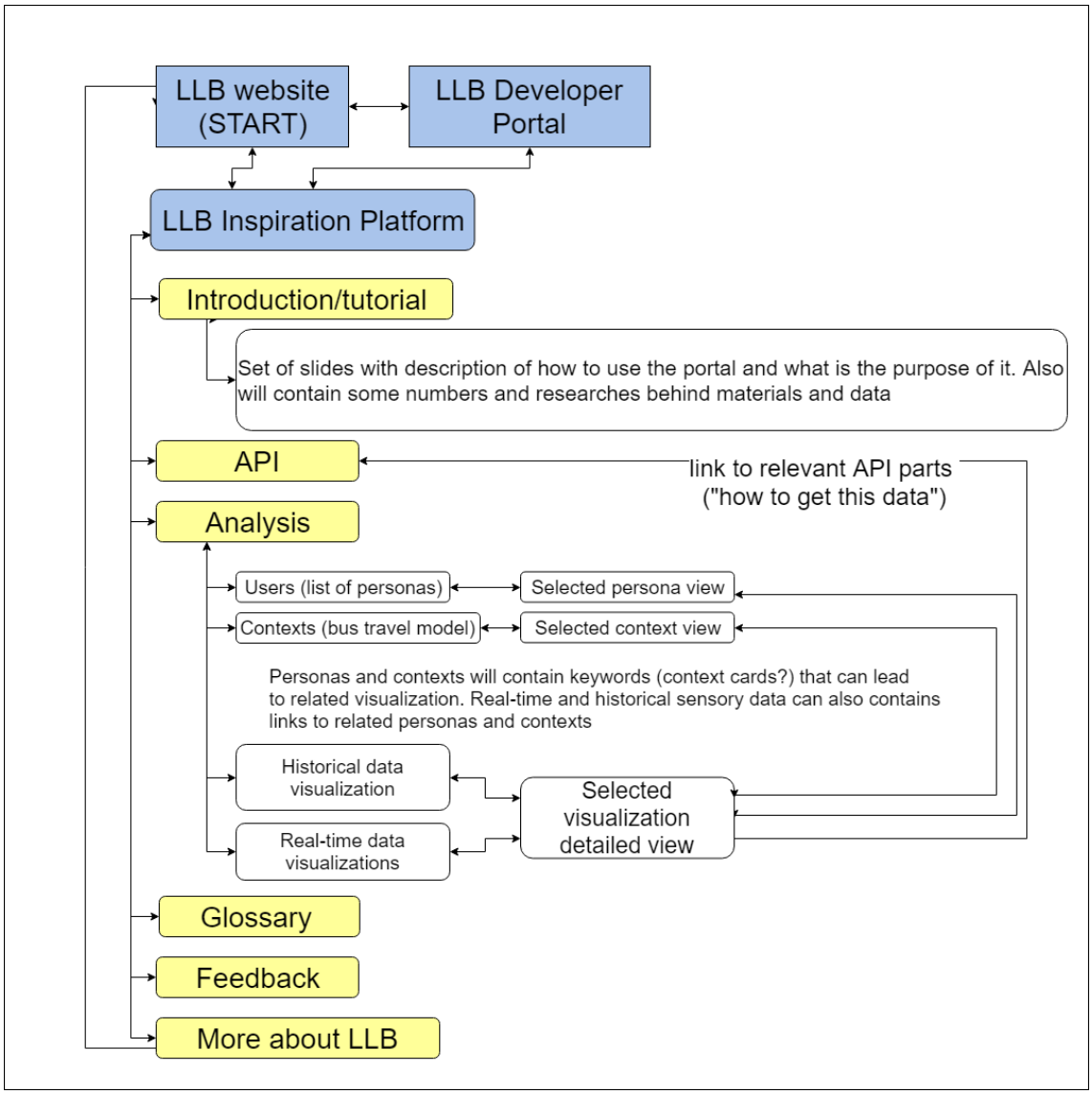



***Figure 6.2**. Original flowchart of LLB infrastructure with integrated prototype. Yellow elements are integral parts of the prototype.*

In terms of actual UI, second flowchart, presented on Figure 6.3, shows general design approach to most of the screens. It also contains some changes from original structure, e.g. exclusion of API documentation due to APIs early development status. Other reason to exclude API was general lack of reference points that Toolkit might refer to when it comes to a specific sensor data for personas or contexts or other Toolkit materials. Major layout would contain header (with logo and LLB website and Developer Portal links) and left sidebar for general navigation.

User would start at the introduction page that would give a choice between introduction text, API access or Analysis section of the portal. Introduction page would textually explain the general purpose of the portal. API access would redirect to the Developer

Portal and its offerings. Analysis link would lead to another list of offerings, presenting Users, Contexts, Historical and Real-time data.

Users page would stand for a list of Passenger Personas, that on its turn would allow user to see a specific Persona and its details as they are presented in paper versions. Persona page would also contain extras from passenger researches, e.g. amount of participants that matches particular personas.

Context page would represent Bus Travel Experience Model that would have same structure as paper original. Each of its contexts and subthemes would have a separate page that would include rich description of them. Both User and Context pages would contain some link to the bus sensor data value that could potentially fit the theme of each of the Personas and Contexts.

Historical data and real-time data links would move user's attention to the same page with sensor data visualizations where user would select a specific date or see the data in the real-time. All the data would be divided onto a several categories and supplemented by a map.

Context Cards and Passenger Journey map would simply listed in each of their own pages and described.

Glossary page would serve the purpose of the vocabulary, containing some of the terms and definitions that developer would not be familiar with. Feedback page would contain a form that developer could fill in order to send some feedback or concerns regarding the portal or its content.

This flowchart was used as a general reference material when it came to the implementation stage.

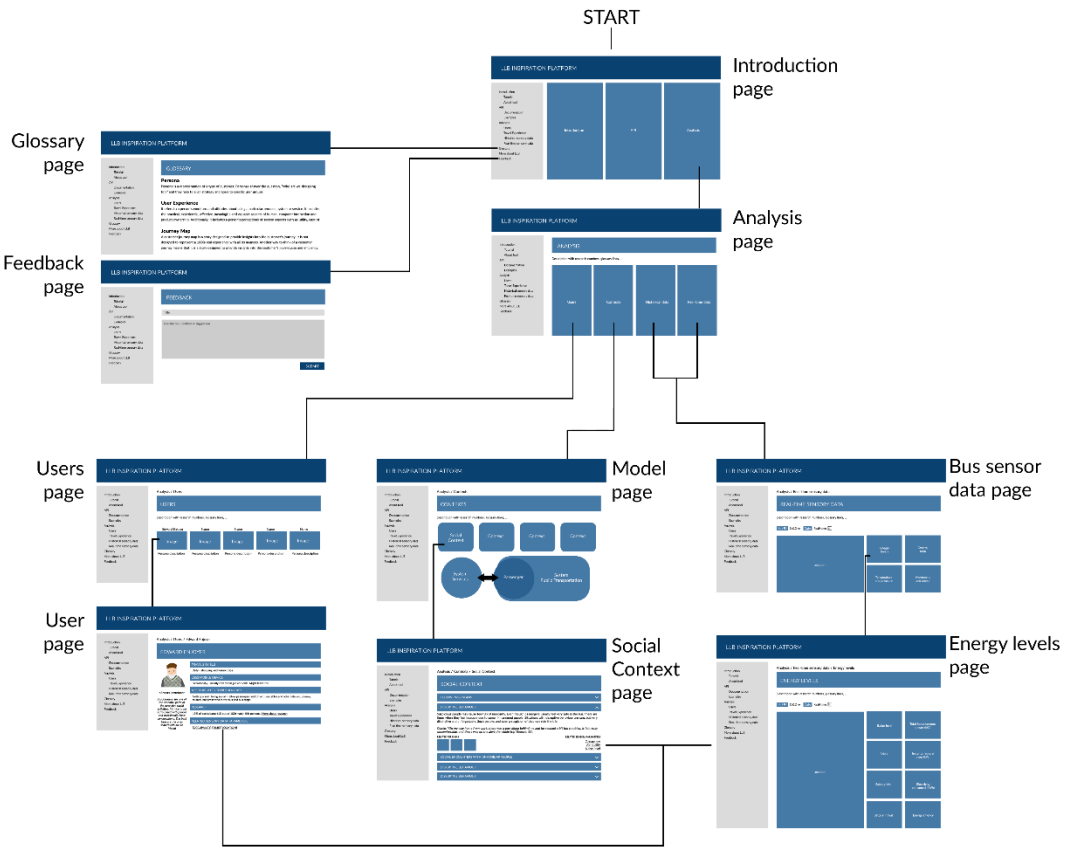



***Figure 6.3**. First flowchart of the prototype with actual UI mock-ups.*

First tangible version of the prototype brought up even more changes to its design and following parts describe these additions and alterations to the Toolkit and prototype in general.

**Passenger Personas**

Passenger Personas pages (Figure 6.4) received most of the changes from the flowchart to reinforce the connection with the rest of the Toolkit. “Related papers” section contains a link to the Resources page where developer will find a list of related papers that describe the process and scientific data behind Personas’ creation. In addition, page includes direct links to other tools that are related to the particular persona thematically and semantically.

In order to expand the navigation options, at the bottom of the page there is panel that can be used for navigating to the next or previous personas so developer would not rely only on navigation links on the left sidebar.

Additionally, instead of using term “persona”, it was decided to use “archetypes” for better resemblance with its content and purpose.

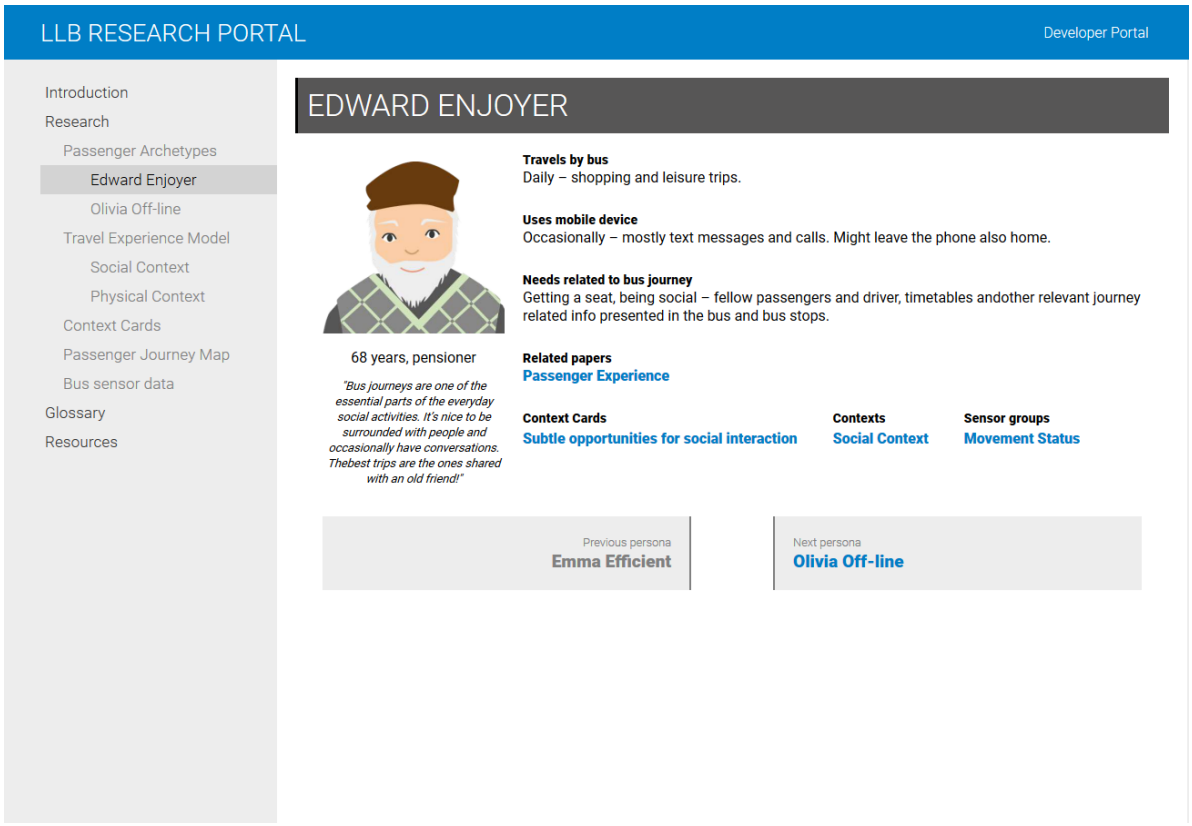



***Figure 6.4**. Passenger Persona page.*

**Travel Experience Model**

Model (Figure 6.5) was introduced in a simpler manner that paper original. In its core, no changes are pushed to its content, but its interactivity. Each of the context blocks were made selectable and each of them lead to a separate page with rich description of context's subthemes. Similarly to Personas pages, navigation panel was also added on each of the Context pages.

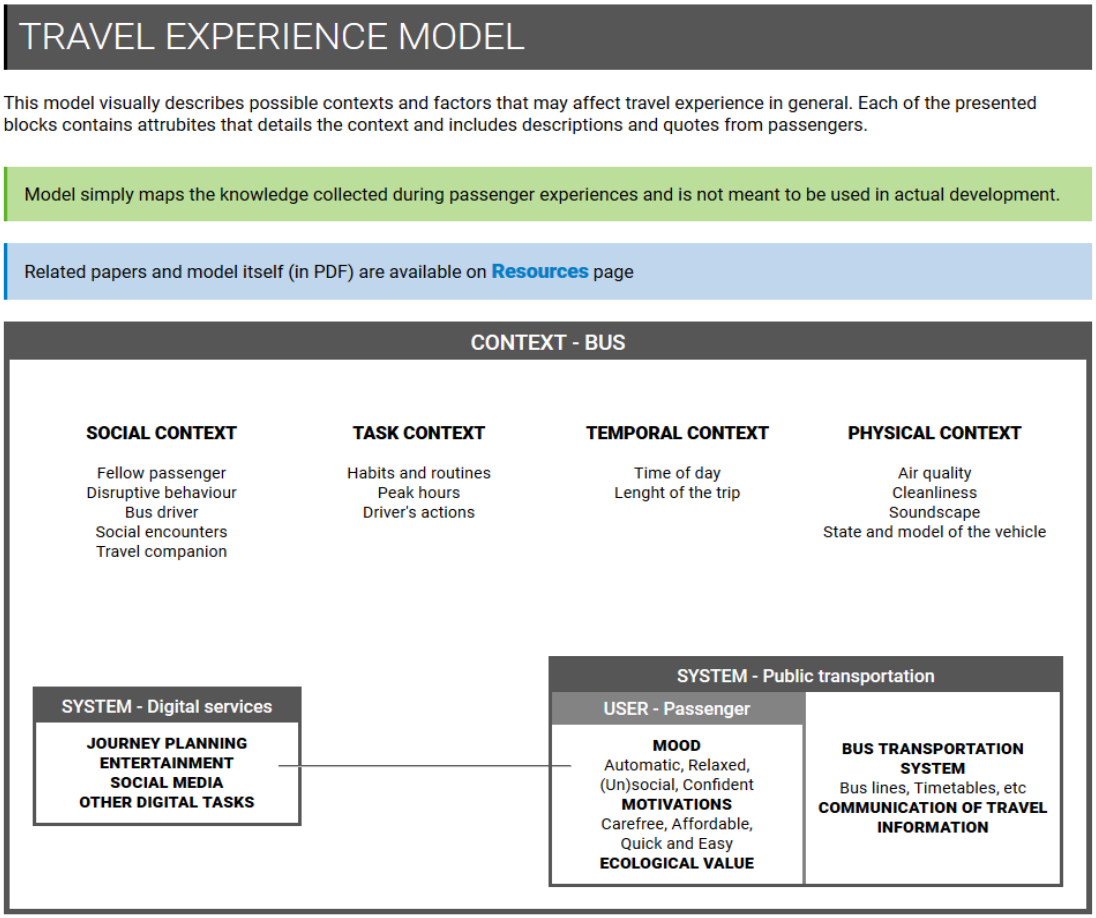



***Figure 6.5**. Travel Experience Model page.*

Context pages (Figure 6.6) contain descriptions and quotes from participants that were involved in passenger researches by Hildén [38]. Furthermore, each of the subthemes is connected to a particular persona, Context Card and sensor group in a form of page links. These connections indicate relation between subtheme and persona that might relate to these themes as important ones. Related sensor group link highlights relevant technical details that may help enrich the insights with real-time data from bus sensors. Related Context Card section shines the light on high-level idea related to a particular subtheme.

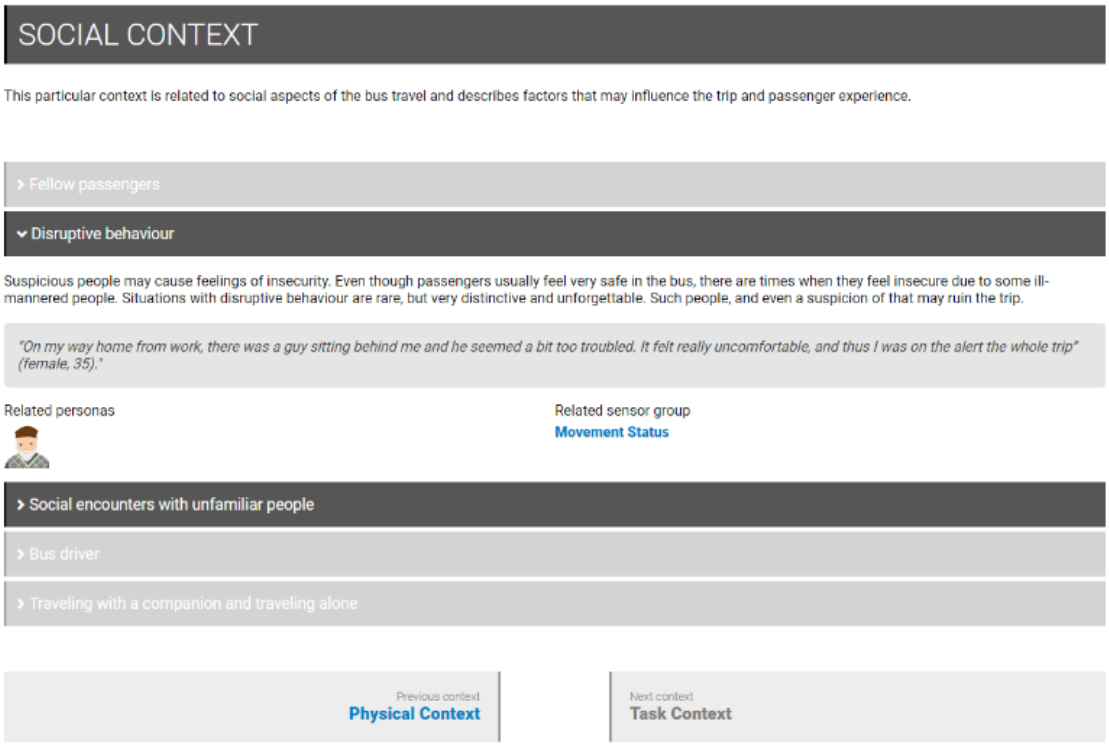



***Figure 6.6**. Context page.*

### Passenger Journey Map

The map (Figure 6.7) is presented as an image and short description of it content and possess no major changes.

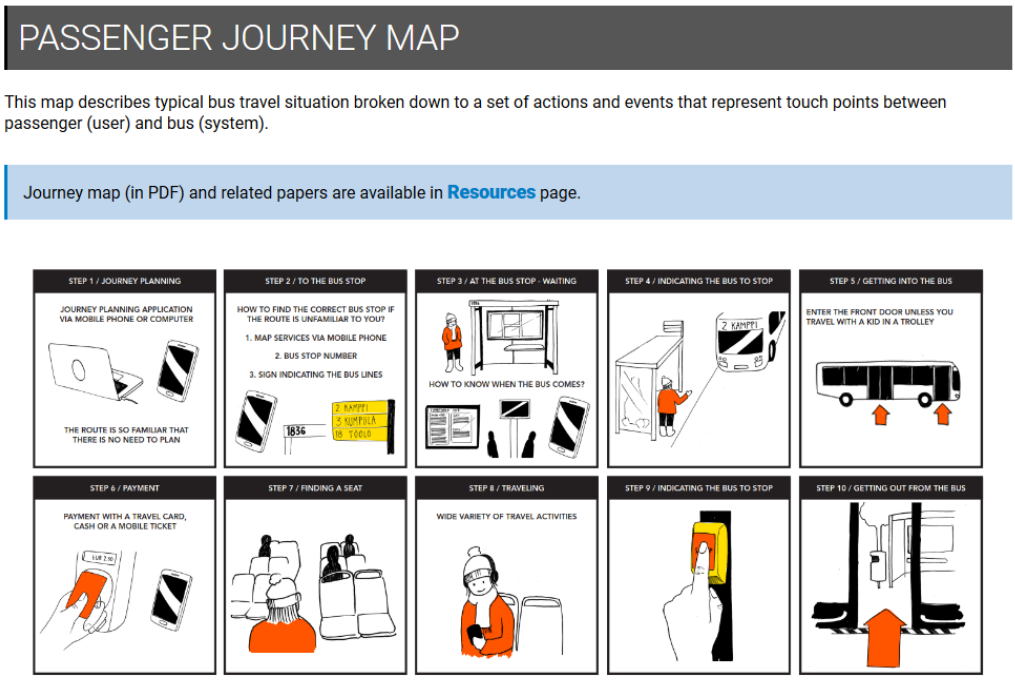



***Figure 6.7.** Passenger Journey Map page.*

### Context Cards

Context Cards (Figure 6.8) are listed on the page and supplemented with short flavour text that enriches the theme of the card with more specific explanation. A short tutorial was also introduced in the highlighted text box.

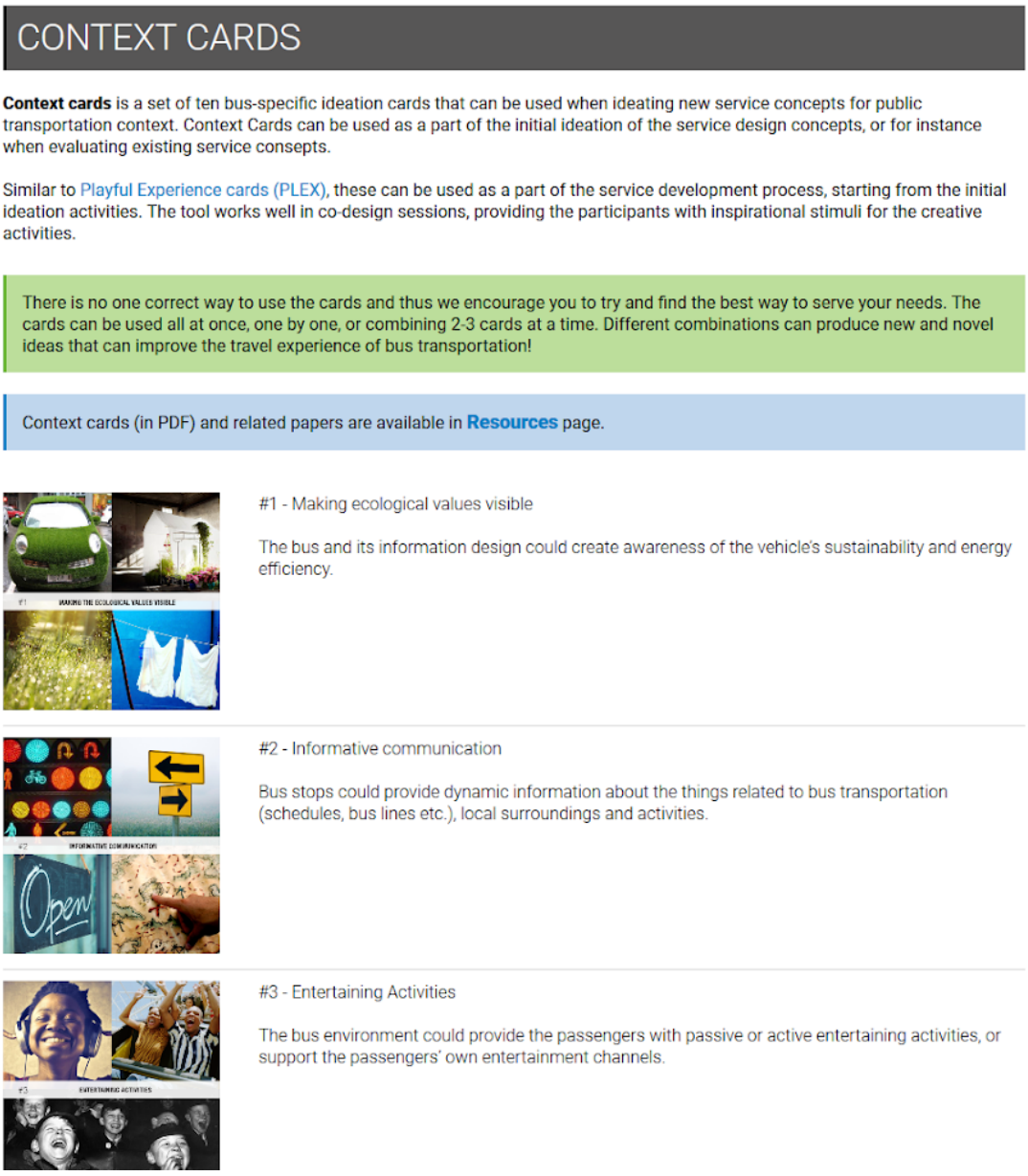



***Figure 6.8**. Context Cards page.*

### Bus sensor data visualization

Major intent regarding sensor data visualization (Figure 6.9) was to show enough technical data to keep developers‘ interested in ways to use this data as source of inspiration or as an example of how it can be used in development. At the same time, these visualizations were not meant to be a fully realized bus sensor data analysis tool.

It is also vital to note that the idea of historical sensor data visualizations was excluded due to the technical complications (lack of back-end infrastructure to fully support server-side rendering and proper data analysis) and time constraints.

For the sake of simplicity and clarity, visualizations took form of text with parameters and their values and geographical map both updated in real-time. Map is intended to supplement partial sensor data snippets to provide more holistic and detail image of the LLB technical environment. E.g. map would provide locational data of the LLB busses and it may specify where e.g. bus inclination, climb or descent is taken place.

Page is also supplemented with basic description of LLB buses, their routes and directions.

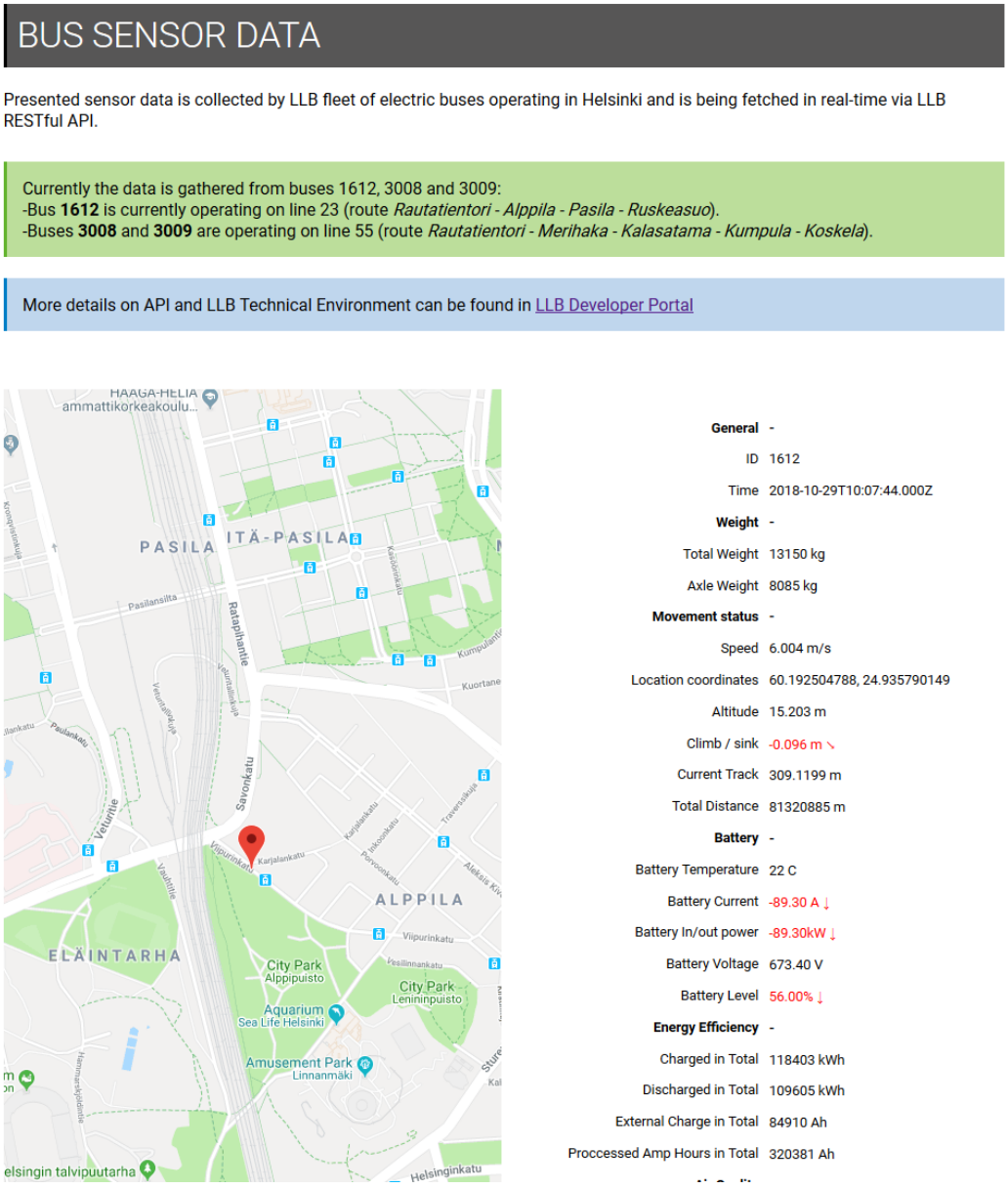



***Figure 6.9**. Bus Sensor Data page*

### Glossary

Glossary page (Figure 6.10) was added as a straightforward answer to the terminology concerns raised during scenario evaluation sessions. Across entire portal, use may notice terminology links that lead to the Glossary page as that contains short definition of the particular term. This idea was also inspired by Redux framework website that has a similar solution to its complex and content-heavy documentation.

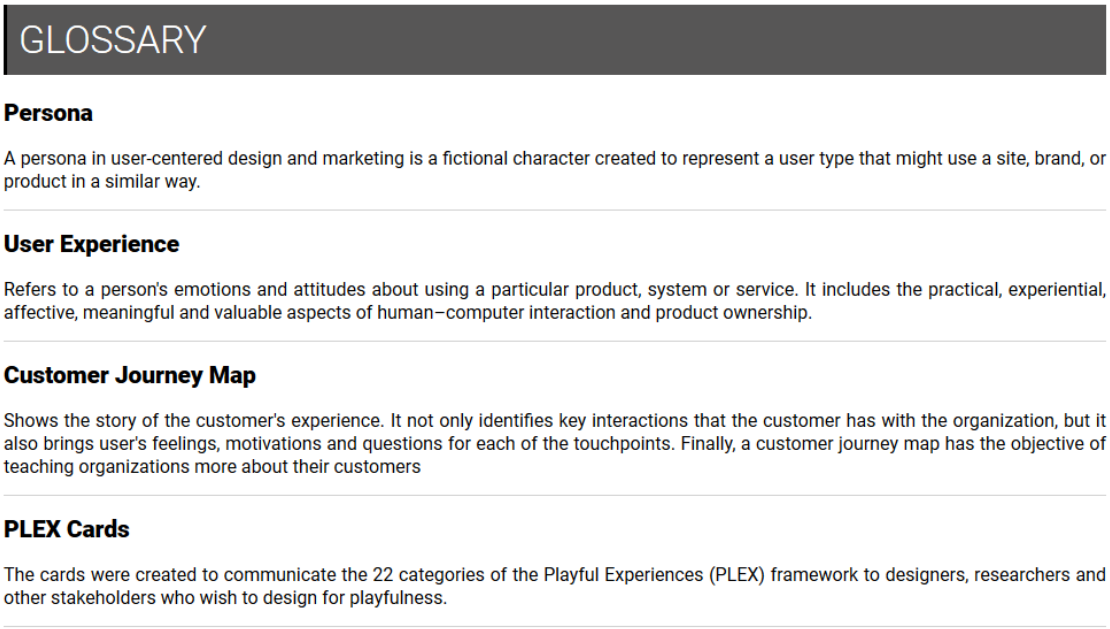



***Figure 6.10**. Glossary page.*

### Resources

This page (Figure 6.11) serves as Toolkit-related library that provides links to the scientific papers written by LLB research staff in regard of passenger experience and published in ACM Digital Library. Resources page was meant to address the lack of available data that is behind the creation of the toolkit as well as provide download link to the Toolkit itself.

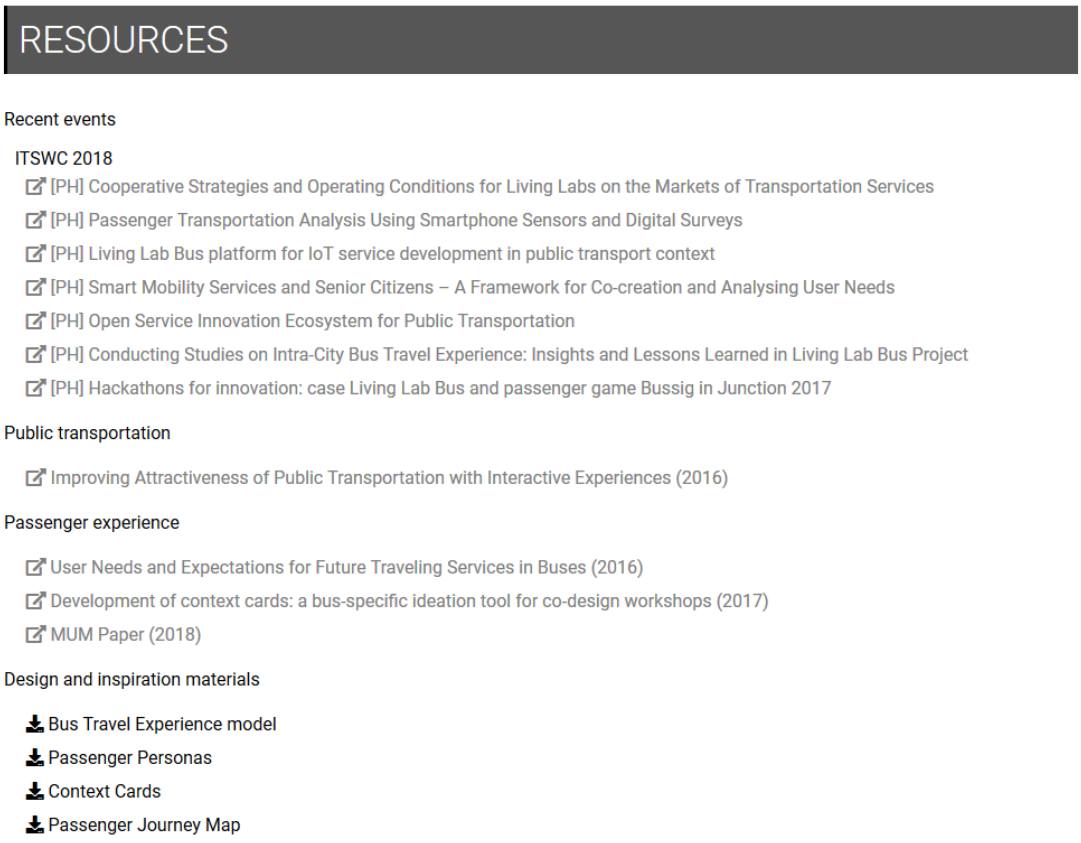



***Figure 6.11**. Resources page.*

## Introduction page

This page (Figure 6.12) greets user with a short introduction and give a short insight of what Toolkit offers to the developer and what is the purpose of this portal. This page is considered as a homepage of the entire portal.

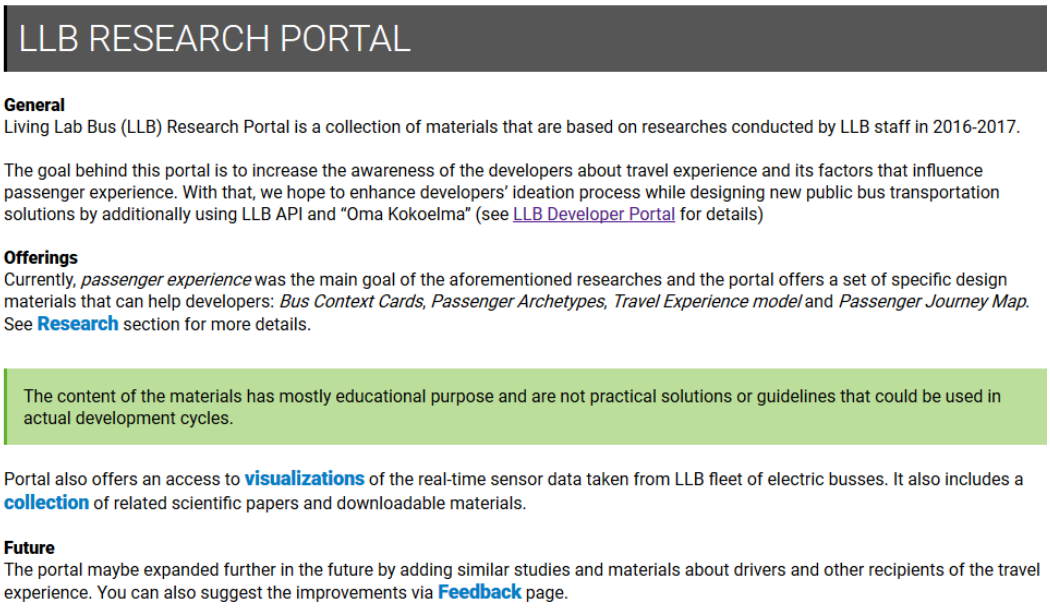



***Figure 6.12**. Introduction page.*

### Conclusion of the first iteration of the prototype

Implemented prototype is the first attempt to address most of the crucial issues and concerns discovered during scenario evaluation sessions. Format of the Toolkit and sensor data visualization are still subjects of change in the next iteration. In the meantime, a general structure of the potential portal and necessary codebase were established and is to be reused in the fourth phase of the thesis work.

Next chapter describes the process and findings retrieved from usability testings that were conducted in order to test its ideas and usage in controlled environment.

# 7. DEVELOPER STUDY - PROTOTYPE TESTING

This section describes the process and results of the third phase of thesis work - prototype usability testing sessions with software developers.

## 7.1. Participants

The recruitment was mostly performed via emails with previous study participants and Doodle form with a list of available time slots for newcomers. Similarly to the last time, the requirement for selection was having a background in programming and/or software engineering. Table 7.1. presents all 8 participants of the test sessions and their background information retrieved from background questionnaires. Average age was 26 years with 22 and 33 years for youngest and the oldest respectively.

***Table 7.1**. Test participants.*

| ID | Age | Gender | Occupancy | Knows about LLB | Other |
|---|---|---|---|---|---|
| **TP1** | 27 | Male | Software developer / student developer | Heard of it, but never used it or looked at it (from a colleague) | Participant from previous study |
| **TP2** | 25 | Male | Software developer / student developer | Yes (participated in previous study) | Participant from previous study |
| **TP3** | 32 | Male | Software developer / student developer | No | Participant from previous study |
| **TP4** | 33 | Male | Software developer / student developer | Yes (previous survey) | Participant from previous study |
| **TP5** | 26 | Male | Other (research assisstant, pervasive computing) | Heard of it, but never used it or looked at it (first time in the session) | New participant |
| **TP6** | 22 | Male | Software developer / student developer | No | New participant (studies UX) |
| **TP7** | 23 | Male | Software developer / student developer | No | New participant |
| **TP8** | 22 | Female | Software developer / student developer | No | New participant |

## 7.2. Procedure and materials

The procedure took place in Tampere University (Hervanta campus) and its premises during November 2018. Each test was screen captured and audio recorded.

Each participant was introduced with consent form and background.

*Consent form* (Appendix H) describes the purpose and procedure of the study, participant's rights and staff obligation to process their data anonymously within Living

Lab Bus project. *Background questionnaire* (Appendix I) was also handed to participants to fill with their personal data. Question were related to their age, gender, occupation and awareness about Living Lab Bus project.

After getting the consent from participant, video and audio recording started and actual test began. *Test tasks* (Appendix J) (Table 7.2) in the amount of six were given to the participants one at the time. Common theme of the tasks was around the idea of participant trying to come up with some public transportation application. General sense of each of the tasks was to hint participant about particular tool, but provide enough ambiguity for free exploration of the portal. First task was used as introduction to the portal. After that, each next task was given to the participants one by one. There was no hard time limit for each of the tasks due to the low complexity of the prototype structure. In case participant having trouble completing the task for more than seven or ten minutes, moderator could give a hint. Participants were also asked to think aloud when performing the tasks.

***Table 7.2**. Test tasks used in the study.*

| | Task description | Target page |
|---|---|---|
| 1 | Get familiar with the portal, its purpose and what kind of design tools it offers. **Find out how these tools were created and based on what researches.** | Portal overall |
| 2 | You start to brainstorm to specify the context and value of your future application. **Find a suitable tool offered by the portal and get familiar with its content.** | Context cards page |
| 3 | You need to think of potential users (passengers) - their habits, needs and preferences. **Find a suitable tool offered by the portal and get familiar with its content.** | Passenger Personas page, Persona page |
| 4 | You need to know when and where exactly your application is used. For example, you can break down a typical bus travel situation and find a point where passengers would use your application. **Find a tool for that purpose in the portal and get familiar with its content.** | Passenger Journey Map page |
| 5 | It is important to know what factors could influence the bus travel for a passenger and therefore - you application usage. You need to see a bigger picture. **Find a suitable tool for that in the portal and get familiar with its content.** | Bus Travel Experience Model page, Context page |
| 6 | After some thinking, you can start thinking about implementation. You need to learn about bus technical details and bus sensor data (location, speed and other parameters) that you could use or visualize in application. **Find related information and examples on the portal.** | Bus sensor visualizations page |

*Post-testing questionnaire* (Appendix K) was given after all tasks being done to capture the initial impressions of the portal. Questionnaire consists of 26 statements that participants had to agree or disagree on a 5-point scale. Statements were divided into several topics: learning outcomes, format of the toolkit, sensor data visualizations,

navigation, layout and visuals, terminology. After filling the questionnaire, interview was conducted. *Interview questions* (Appendix L) were introduced in 6 topics: overall impression from the prototype, visuals and layout, Toolkit properties, learning outcomes, returnability, overall satisfaction.

## 7.3. Completion rates

ISO [42] describes several usability metrics that can be used to evaluate how effective and accurate user can achieve his goal by performing some tasks in some system or product. One of the most fundamental metrics is *effectiveness* or *completion rate* and it can calculated by following formula (7.1):

$$\text{Effectiveness} = \frac{\text{Number of tasks completed successfully}}{\text{Total number of tasks undertaken}} * 100\% \qquad (7.1)$$

In order to get the most out of the data, some changes were introduced to the formula. Completion rate was calculated for each of the participants to see how successfully they managed to use the prototype. Each of the tasks had a completion criteria that had its own numeric value. Criteria can be found on Table 7.3.

***Table 7.3**. Task completion criteria.*

| Task completion criteria | Criteria description | Criteria value |
|---|---|---|
| Done | Task was successfully completed without any hints from moderator | 2 |
| Partially done | Task was successfully completed with some help from test moderator | 1 |
| Failed | Task was not completed | 0 |
| | **Total points** | **12** |

New formula (7.2) for calculating effectiveness in the context of each participant:

$$\text{Effectiveness} = \frac{\text{Number of points for completed tasks}}{\text{Total number of points for task being “Done”}} * 100\% \qquad (7.2)$$

Table 7.4 demonstrates criteria values and calculated effectiveness of each of participant for each task.

***Table 6.4**. Completion rates calculated.*

| | TP1 | TP2 | TP3 | TP4 | TP5 | TP6 | TP7 | TP8 |
|---|---|---|---|---|---|---|---|---|
| **Task #1** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Task #2** | 2 | 1 | 2 | 2 | 2 | 1 | 0 | 1 |
| **Task #3** | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Task #4** | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 |
| **Task #5** | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Task #6** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **Effectiveness, %** | **83,3** | **91,7** | **91,7** | **100** | **100** | **83,3** | **83,3** | **91,7** |

On average, completion rate is **90,6%**, which is a better result than industry average rate of 78% and bigger than average for assessment tests in general (86%) [52]. This result indicates a success in terms of prototype usability.

## 7.4. Questionnaire results

First section of the questionnaire (Figure 7.1) was meant to evaluate a certain properties, related to feel of novelty, perceived value and applicability of the content in real projects. As a result, developers had these attributes in high regard.

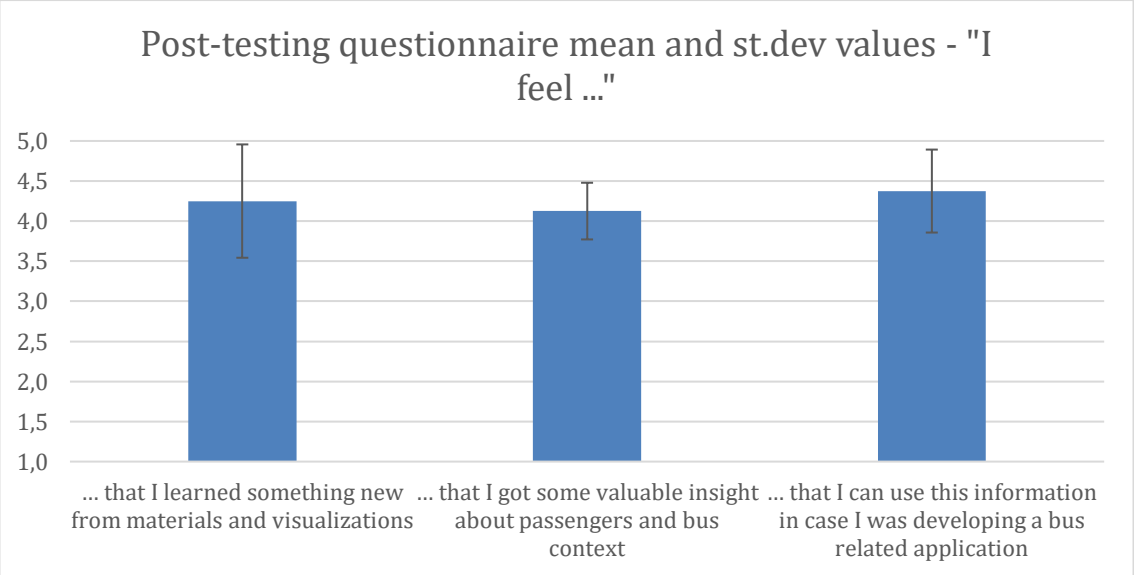



***Figure 7.1**. Mean and standard deviation values for questionnaire section related to novelty properties of the prototype (N=8).*

On Figure 7.2, it is clearly seen that participants were quite satisfied with the format of the Toolkit, but Travel Experience Model gained the lowest score.

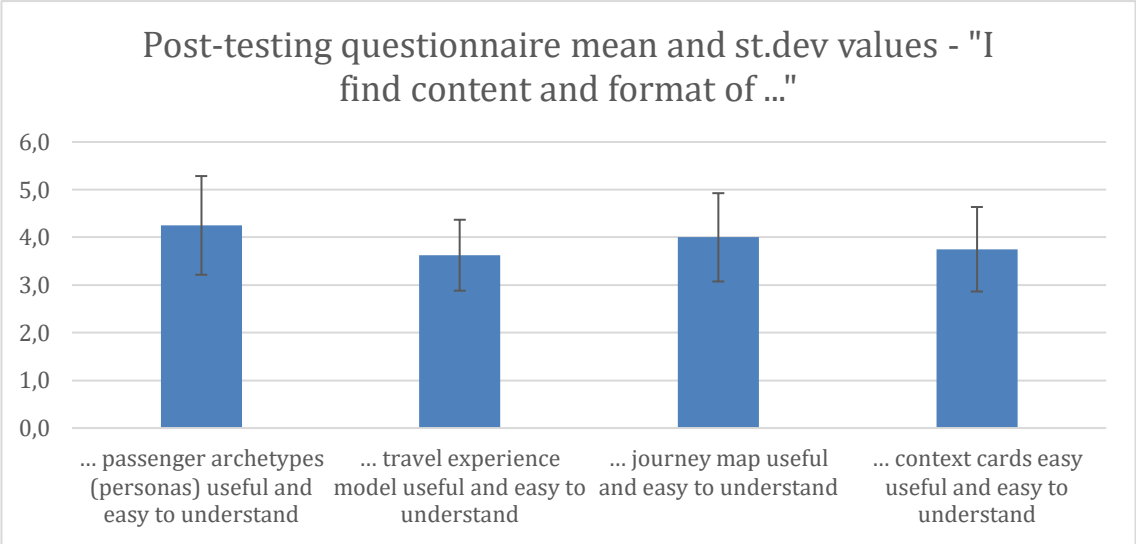



***Figure 7.2**. Mean and standard deviation values for questionnaire section related to Toolkit materials pages properties (N=8).*

Figure 7.3 shines the light on sensor data visualization properties. While the goal of giving enough technical information in a visually pleasant ways seems to be achieved (first bar), value of its addition to the general knowledge of bus environment, its connection with the Toolkit and richness of visualizations themselves got lowest scores.

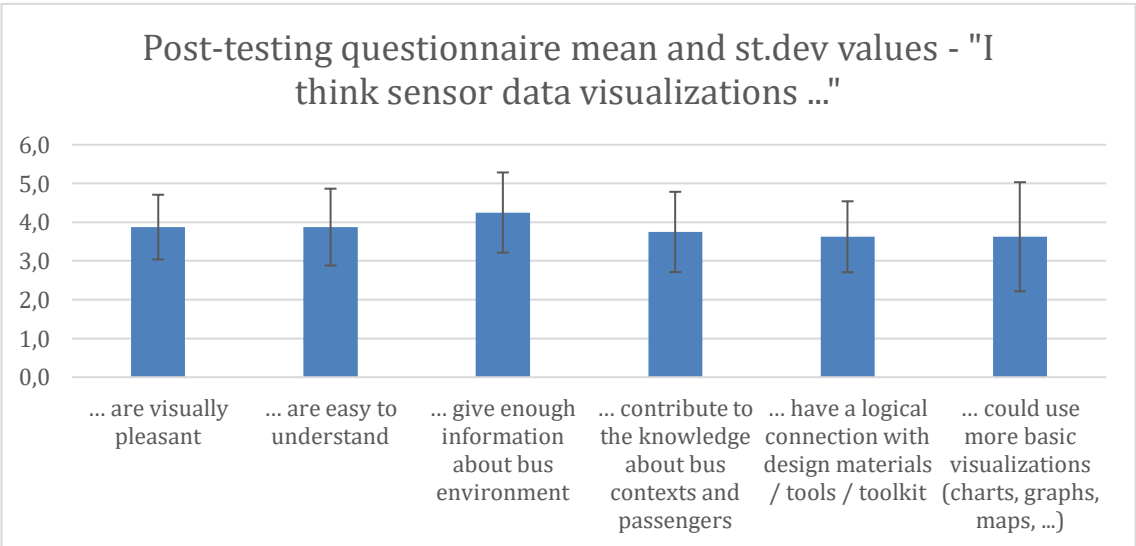



***Figure 7.3**. Mean and standard deviation values for questionnaire section related to sensor data visualizations (N=8).*

In terms of navigation, there were some problems with easiness of use that is clearly seen in the bar chart on Figure 6.4. Familiarity of the layout and logic behind it were positively rated.

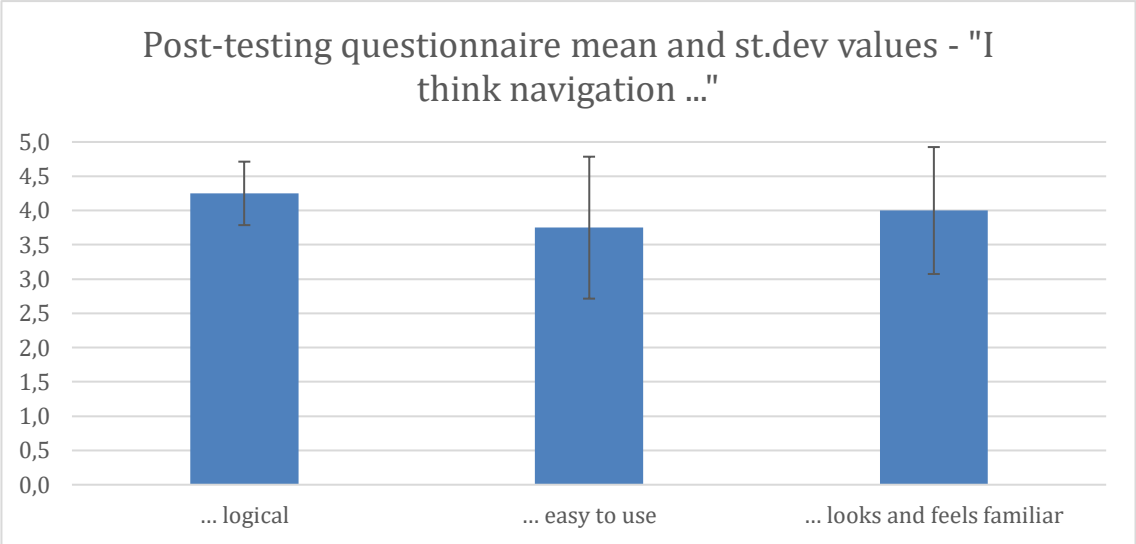



***Figure 7.4**. Mean and standard deviation values for questionnaire section related to prototype navigation (N=8).*

Structure and visuals of the prototype were also positively perceived - as presented on Figures 7.5 and 7.6. Though its feel of being up to the modern visual design standards was a slight concern from the participants as they rated it almost neutrally. It is worth to mention that prototype managed to achieve some familiarity with the similar websites.

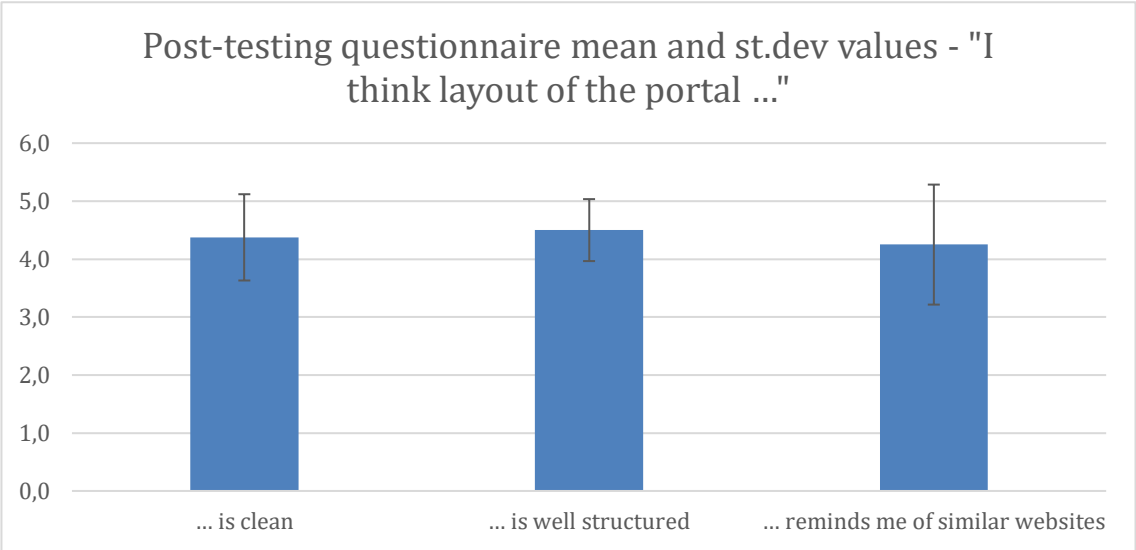



***Figure 7.5**. Mean and standard deviation values for questionnaire section related to layout of the prototype (N=8).*

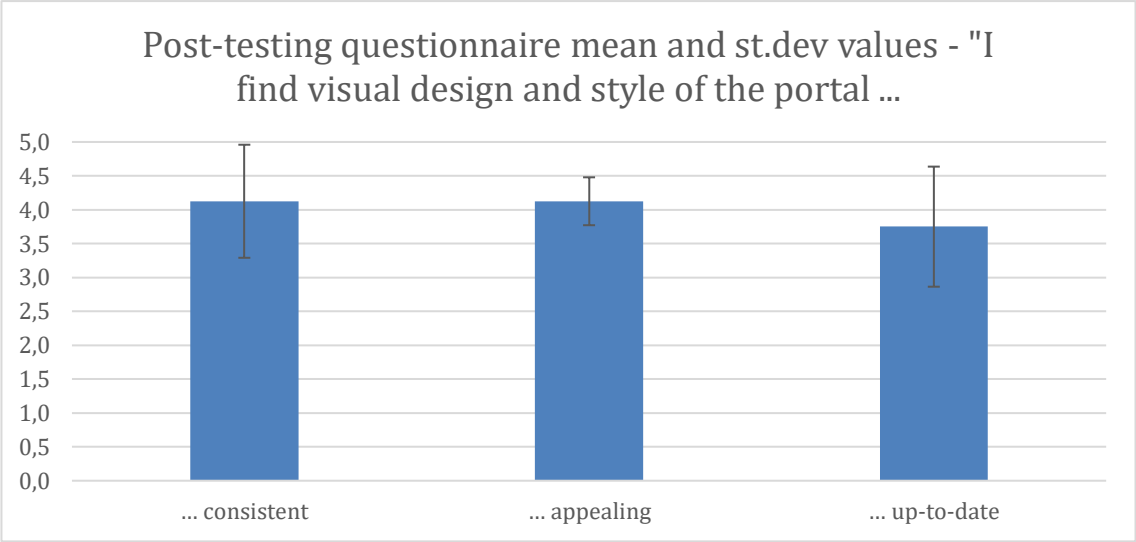



***Figure 7.6**. Mean and standard deviation values for questionnaire section related to visuals of the prototype (N=8).*

Terminology (Figure 7.7) received the lowest score in terms of understandability, but participants high scored logic behind presented terms and definitions.

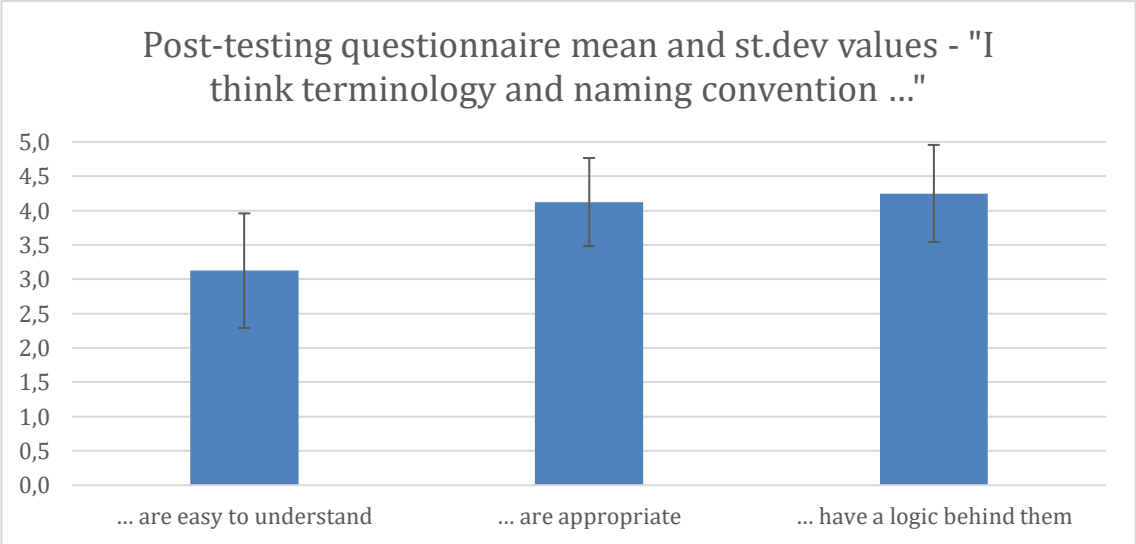



***Figure 7.7**. Mean and standard deviation values for questionnaire section related to terminology (N=8).*

## 7.5. Interview findings

### Navigation and layout

Some of those participating the study had some minor worries about the visuals: "*There is nothing clearly wrong, but needs improvement.*" (TP1). Same participant noted lack of «wow» effect and simplicity of prototype's looks and other (TP7) wanted

to see more complex graphics. Some of them (TP1 and TP2) mentioned that the sidebar contain too much grey text on a grey background and it was a minor obstacle for them. Nevertheless, most of the time participants liked the layout and it reminded them of similar website with familiar structure: ""*Looks professional and finished*" (TP6). Coloured highlights on the pages were mentioned separately, TP3 and TP6 reported that it helped them to quickly understand the gist of the material.

TP1 additionally suggested to add some mouse over tooltips or even replace entire Glossary with pop-up windows with terminology definitions.

**Toolkit pages feedback**

Situation with the Toolkit changed almost vice versa to the scenario reading results. There still was slight confusion with the materials: "*Context Cards - not really get into them either*" (TP5). "*What is the difference between cards and contexts?*" (TP4). One participant also pointed out Toolkit application as it focuses attention of things that she would not generally think about: "*It is kind of a common knowledge but I haven't talked about it so well I don't think if I would develop an application without this data. Not sure if I would realize all different users.*" (TP8).

Passenger Personas page were greeted with more positivity than during scenario readings: *"Passenger Archetypes was quite useful or at least for the task I was doing"* (TP5). TP1 expressed a desire to see more information on page: "*I would find more interesting to see how often [Edward] use the bus*". Same participant also expected to see some kind of short preview of the available personas.

Journey Map and Context Cards did not receive any specific feedback and participants were generally satisfied with them: "*Journey map was very intuitive to have there.*" (TP5). TP2 noted that he indeed would use Context Cards for determining use cases during brainstorm sessions. Another participant (TP5) defined his own use case for the map: "*This is at least useful for defining usual habits of the passenger.*". TP8 pretty much quoted one of the user tasks that was used to establish a vision for the prototype: "*I would use this to figure out where app is used, what it needs, how fast it should be*".

Travel Experience Model page on the other hand was not as praised: "*Looks unfinished*" (TP4). "*I didn't really get into much*" (TP5). Other participant (TP6) was completely lost on both Model and Context pages. Model page was also lacking some signifiers that could indicate that context blocks are selectable and clickable (TP1).

Important to note the ways participants found and used the Toolkit and visualizations during the test. TP1 explained his approach to usage of similar documentation: "*It takes different approach to develop something that I usually have... I very rarely start from*

*perspective that okay we have all of this information available, how could we use it. Even when I have some info, I most of the time I have some idea how to use it. At the same time I can remember situation when I have a lots of data that I could utilize in some way, but in the end I wasn't able to implement anything as I didn't have idea how to use it. Portal like this would help more if it does not give me plain documentation.*". Some were trying to combine the tools, e.g. map and the sensor data: "*In a specific situation maybe bus sensor data could be used. I could use both.*" TP5). One participant was trying to use Passenger Journey Map in Personas-related task: "*It would be beneficial once we have a wider collection of personas, trying to profile persona on each phase."* (TP4).

Also, quite a few participants (TP1, TP3 and TP6) mentioned a need for better introduction to the materials and how to use them.

**Bus sensor visualizations**

Most of the concerns were focused around visual representation of text data. Due to the large amount of technical parameters, TP2 and TP3 suggested to add some functionality to hide some of the information. TP2 was very eager to use and explore this particular page instead of Toolkit for each of the tasks. Overall, participants were pleased to explore this page and see variety of the data..

**Name of the portal**

Participants were asked how would they rename the portal so it would indicate its purpose better. Half of the participants would rename it and most of the suggestions were about mentioning "tool" in the title.

**Research data availability**

A question of research papers availability via e-journals and digital libraries was raised by TP3: "*If I work for a company, how can I access the paper? It is impossible.*". Same participant also wanted to see actual content of the papers as a web content and not as a downloadable pdf. Having a download link on each individual tool page instead of keeping them exclusively on Resources page was proposed by TP8.

**Terminology feedback**

Change of names and some terminology improved the situation that occurred during scenario readings. Though there was still slight confusion: "*I was little confused with these titles*" (TP2). TP8 was a bit puzzled with "Research" section of the prototype as it contained inspiration materials instead of research tools as he expected. But in the end, there was no question raised about the meaning of any terminology presented.

### General satisfaction with the prototype

In the end of the interview, participants were asked to verbally rate the prototype from 1 to 10 within three categories: aesthetics and visuals, usability and ease on use and general usefulness. The purpose of that was to see how participants would react to the prototype after some reflection and discussion during the interview. Results were quite positive: "*Very useful, I would give ten, I had one course in which I have to make a bus app and we didn't have this information but [portal] would make it much easier*" (TP8). Mean values and standard deviation can be seen of Figure 7.8.

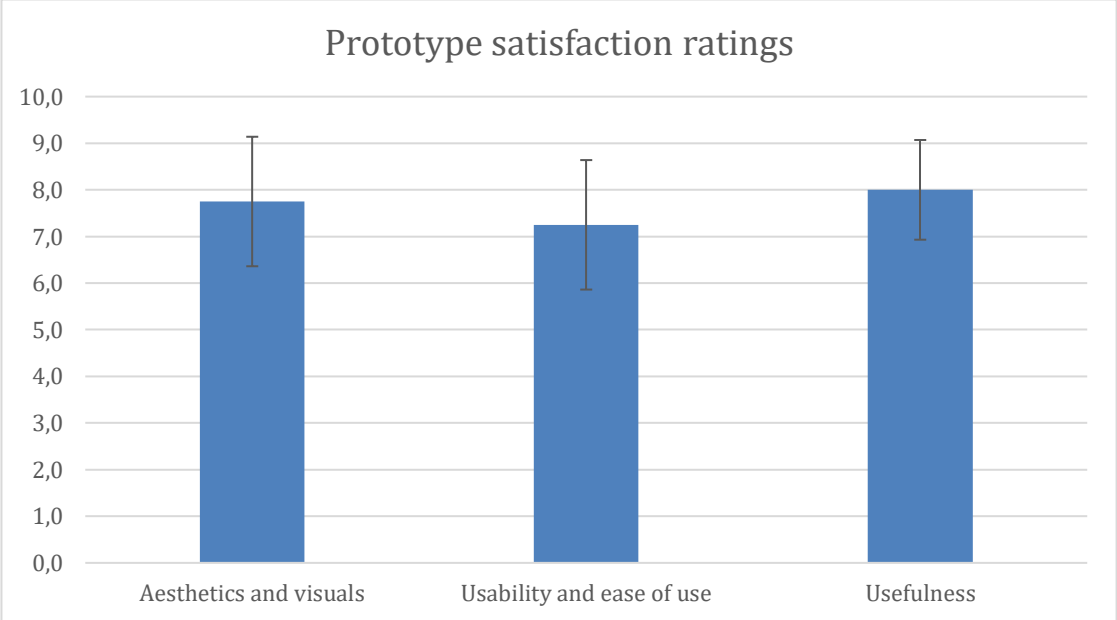



***Figure 7.8.*** *Mean and standard deviation values of prototype satisfaction ratings (N=8).*

### Conclusion of the usability tests

There was no any significant obstacles and problems discovered during the testing and most of them were related to the visual design and some minor functionality.

Major takes from the test indicate that the prototype may enable the developers to explore more ways of using the Toolkit than anticipated. Study also confirmed that the current vision and structure of the prototype can be considered workable and pleasantly looking for developers.

Next major and final iteration of the prototype will include necessary fixes and adjustments and it will be covered in the next chapter.

# 8. PROTOTYPE REWORK

This section describes the fourth phase of the thesis work – prototype revision based on the feedback from previous study and delivery.

## 8.1. Prototype changes

**General**

While the general structure was positively received, some of the raised issues were needed to be addressed. Most problematic part of the first version of the prototype was the Travel Experience Model page. The layout of the model was not perceived as interactive as anticipated and it was the major subject to change. Furthermore, developer did not expressed a strong opinion on interconnectivity of the tools. It led to a major visual change to the general page layout with the introduction of a new highlight field. Additionally, all of the Toolkit content was introduced in the prototype.

Mentioned new highlight field was designed to isolate tool content and tools relationships from each other alongside with other extras. It can be seen on a new Persona page (Figure 8.2). Furthermore, each of the highlighted fields has a set of tooltips that explain the relationship between tools. This new highlighted area was outlined with a top blue line and light blue background visually separating actual material content from related materials. The field was intended to outline the importance of the connection between tools and draw user's attention to the other tools.

Navigation panels that allowed to switch between Personas and Context Cards were supplemented with a link to the tool introduction page. It was introduced to provide more clarity by making introductory content more reachable at any moment. Additionally, similar idea was applied to entire Toolkit. It is now possible to switch between actual tools themselves, as may seen of Figure 8.1.

Name of the portal was decided to be "Bus Travel Experience Toolkit" for better resemblance with its content and nature. Additionally, previous "Research" section was also replaced with the same title for sake of recognizability.

Each of the material page received a separate PDF-file download link at the title field of the page. This decision was motivated by simple convenience this decision could bring to a developer.

Sidebar received a new interaction. When it is not focused by the mouse, it now slightly fades out, making the central body of the page to stand out more.

### Passenger Personas pages

Personas introduction page (Figure 8.1) contain same list of personas, but it was supplemented with a short preview of each of the personas and age group categories. It was added to address the introduction issue in a compact format that gives a quick overview of the tool.

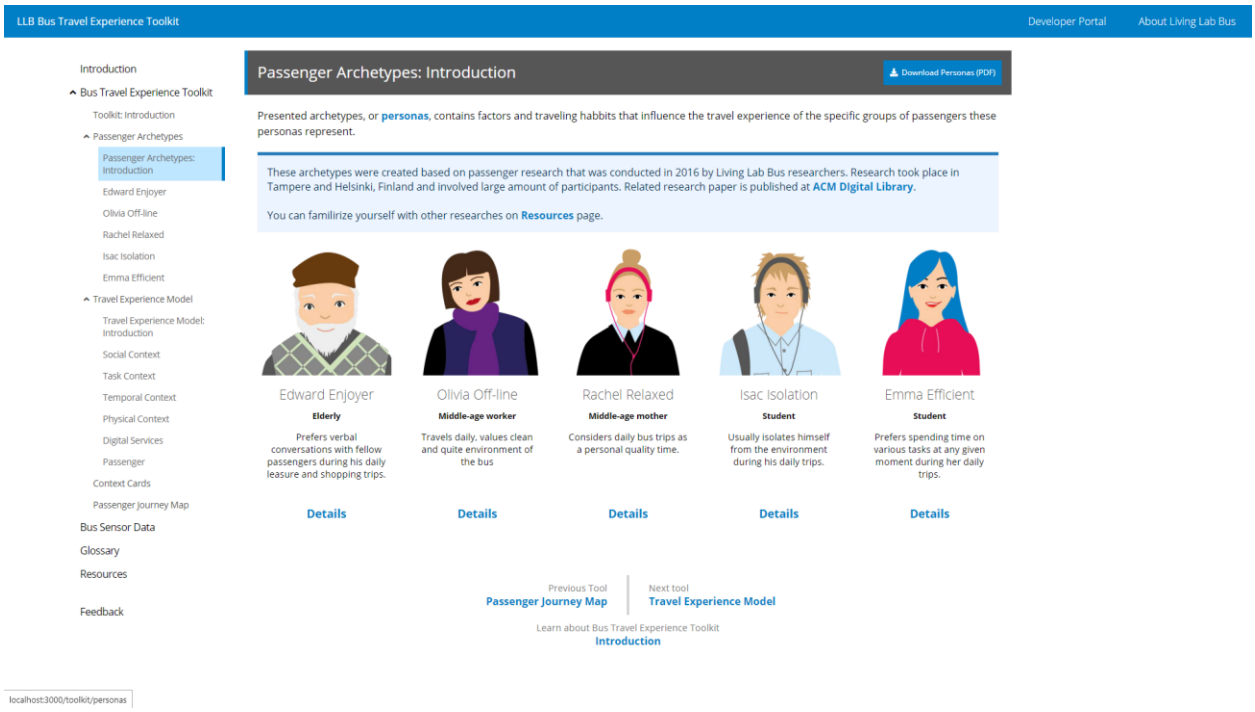



***Figure 8.1**. New persona introduction page - enriched with short previews of each of the personas.*

Persona page (Figure 8.2) received some additional links to a wider range of contexts of Travel Experience Model. All personas additionally got a source link to the paper that describe research on passenger experience done by Hildén et al [38].

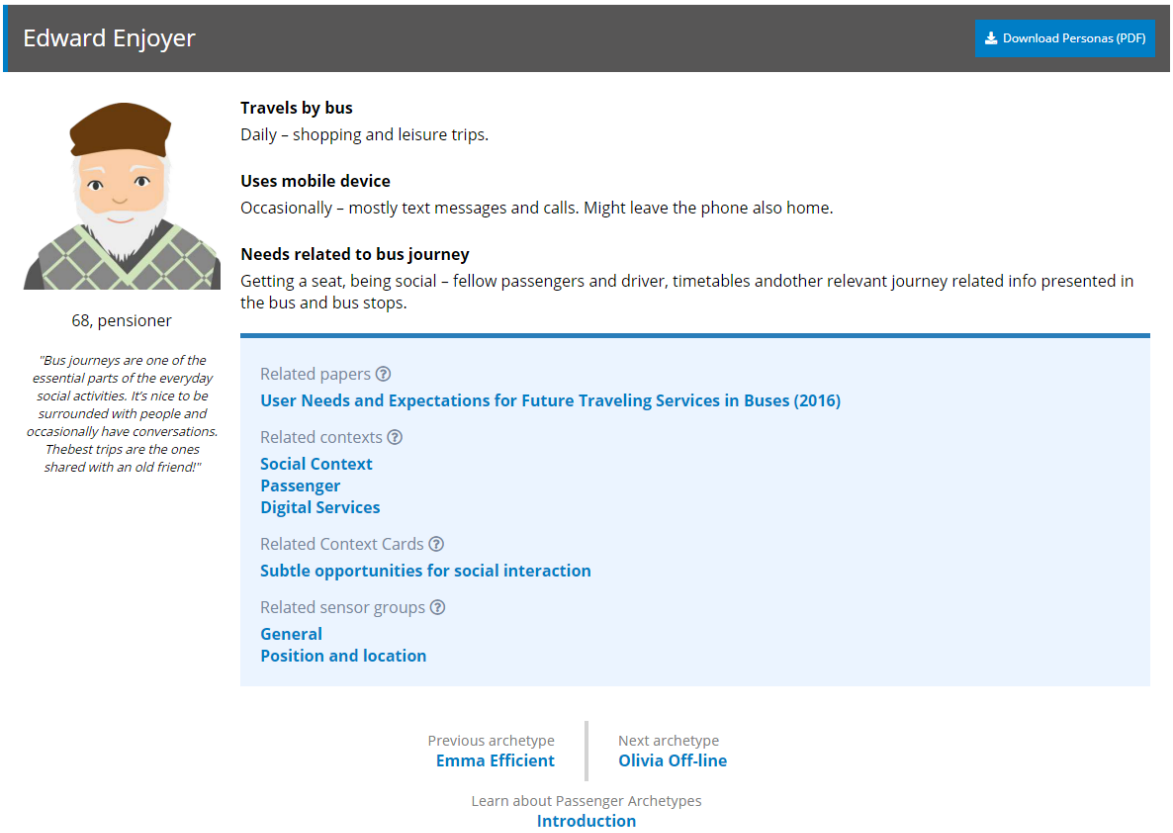



***Figure 8.2**. New persona page - received changes to a highlighted area that contains tooltips and more connections to other materials.*

### Bus Travel Experience Model

This tools received the most extensive revision (Figure 8.3). Instead of replicating paper original, contexts are just listed in a form of basic text blocks that lists context subthemes. Necessary relationships in the lower part of the model were replaced with icons and text descriptions for better clarity. Context titles were turned into more visible links that lead to a relevant Context page.

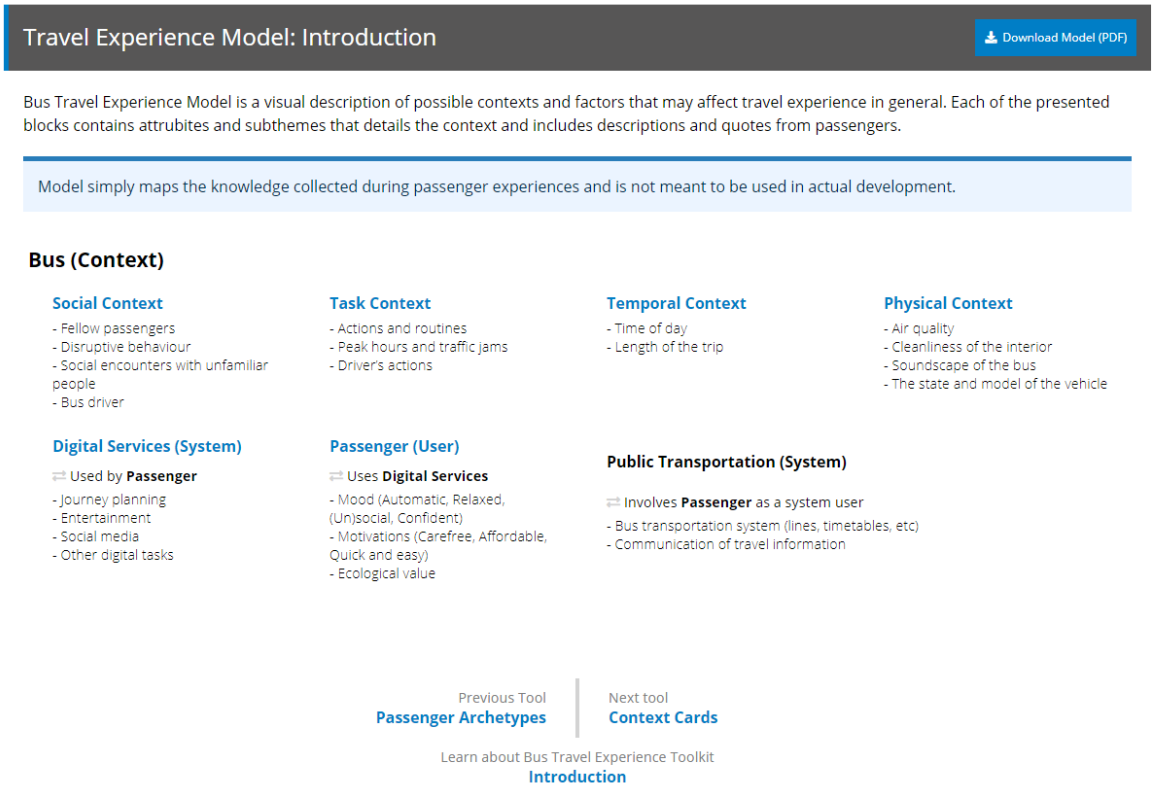



***Figure 8.3**. New model page – simplified and streamlined for a better clarity.*

## Context Page

This page (Figure 8.4) was also a subject of some major visual change. Related materials and sensor groups are now grouped inside highlighted area, similar to Personas page. Each of the material is supplemented with tooltips that explains the connection.

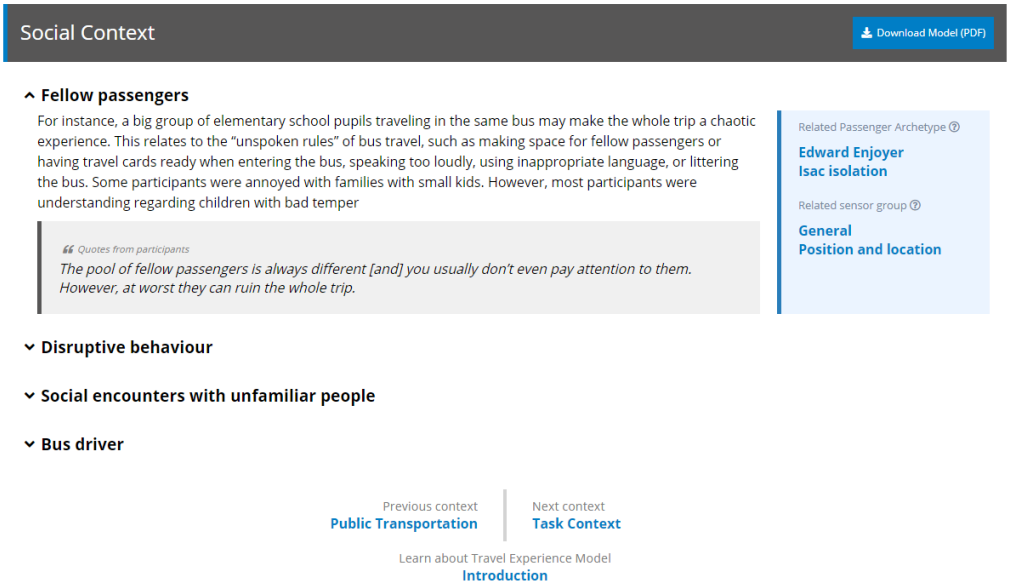



***Figure 8.4**. New context page – new element grouping and simplified visuals.*

### Passenger Journey Map

This page (Figure 8.5) was not changed aside from general colour and structure adjustments other pages received. Only addition to that was a separate view of the Journey Map in higher definition on a separate browser tab.

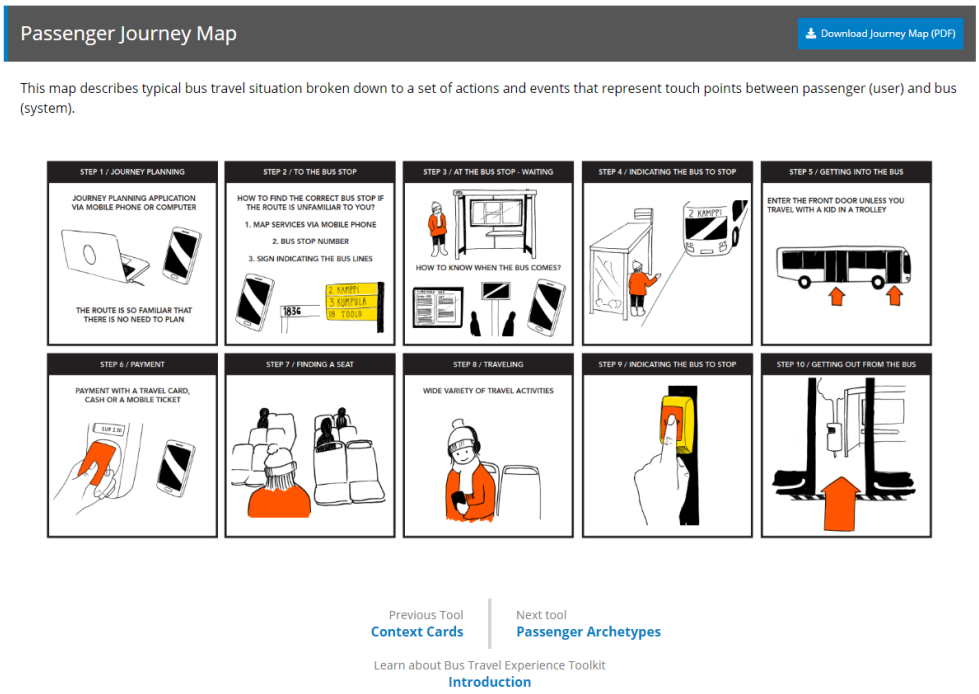



***Figure 8.5.*** *Journey Map page did not changed much from the previous iteration as participants did not have any issues with it.*

### Context Cards page

Major addition to the page (Figure 8.6) was a proper gallery view that allows user to see the cards in higher definition.

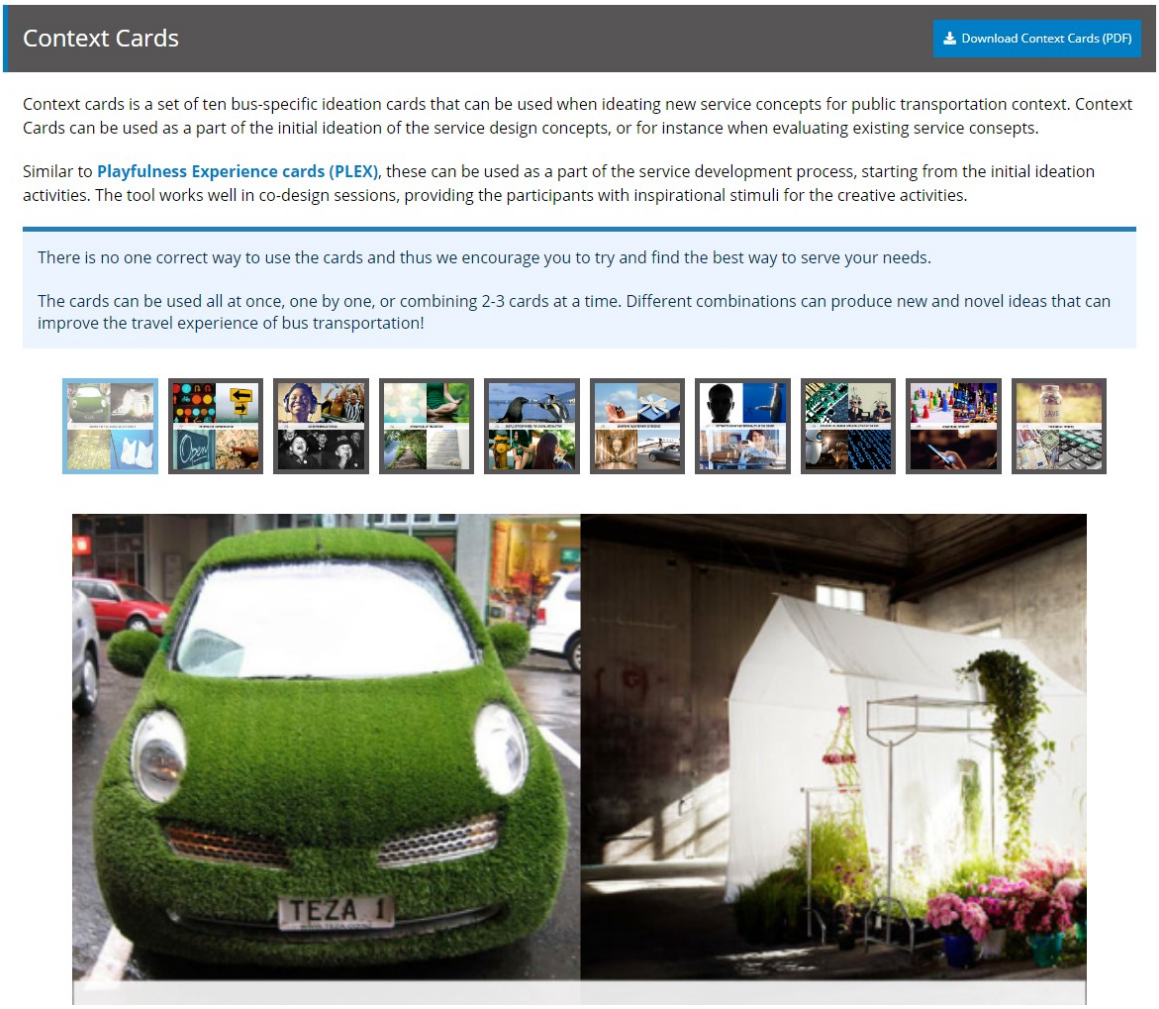



***Figure 8.6**. Context Cards page received a functional gallery for better view of their content.*

### Bus sensor visualizations

This page (Figure 8.7) got several visual changes. While visualization set remained the same (map with parameters and their values), some collapsible elements were added, allowing user to hide some of the groups of parameters. Parameter values also receive a more compact view. Those were the only concerns raised by the participants. In addition to that, page now contain all possible parameters from the bus sensors.

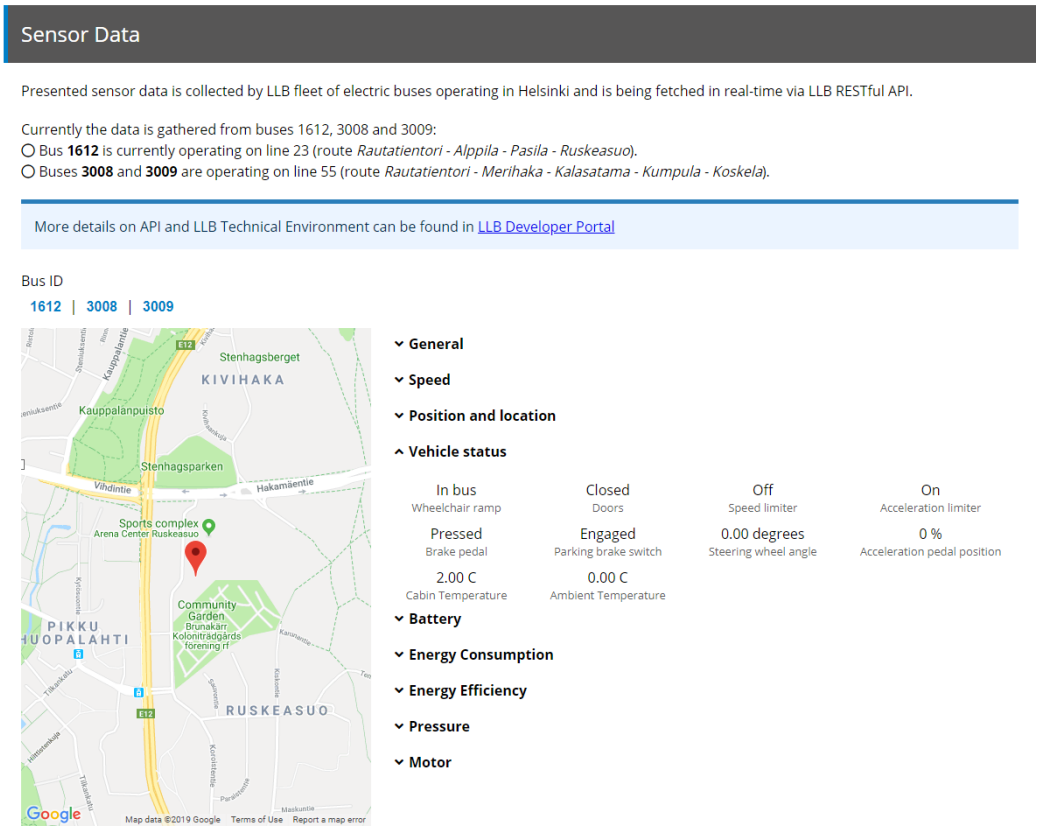



***Figure 8.7**. More refined visuals of the bus sensor visualizations - collapsible sensor blocks and compact parameter view.*

### Glossary page

Similarly to Journey Map, page was not changed dramatically as developers did not react to this page to any significant degree (Figure 8.8). The only addition was a new minor mouse interaction that highlights definition block on mouse over. It was made in order to make purely textual content more lively and responsive to user's action.

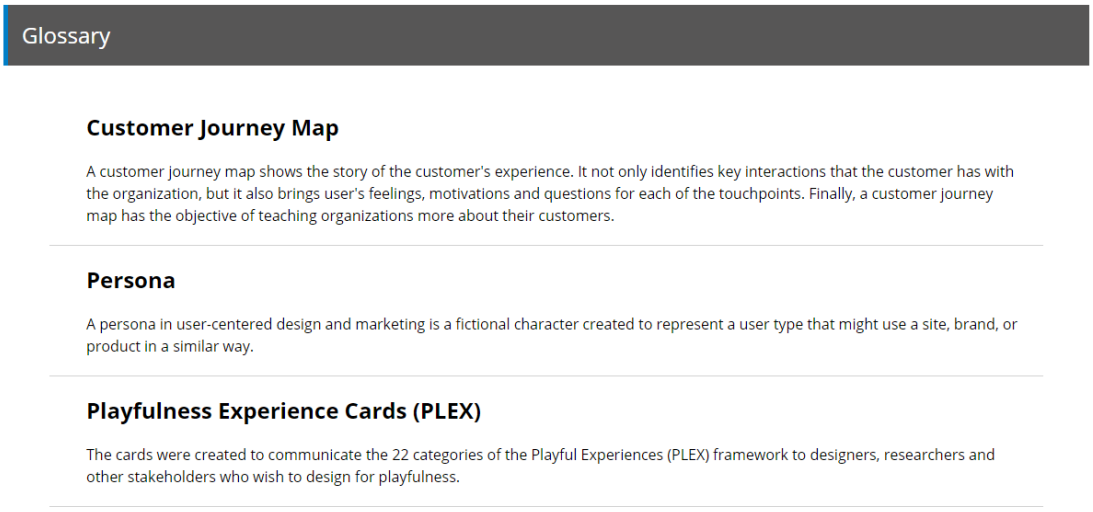



***Figure 8.8**. Glossary page did not receive any major changes.*

### Introduction page

This page (Figure 8.9) received a major overhaul and now serves as a proper starting page with a short and engaging descriptions of the Portal offerings. Each of the icons is clickable link that lead to the respective page.

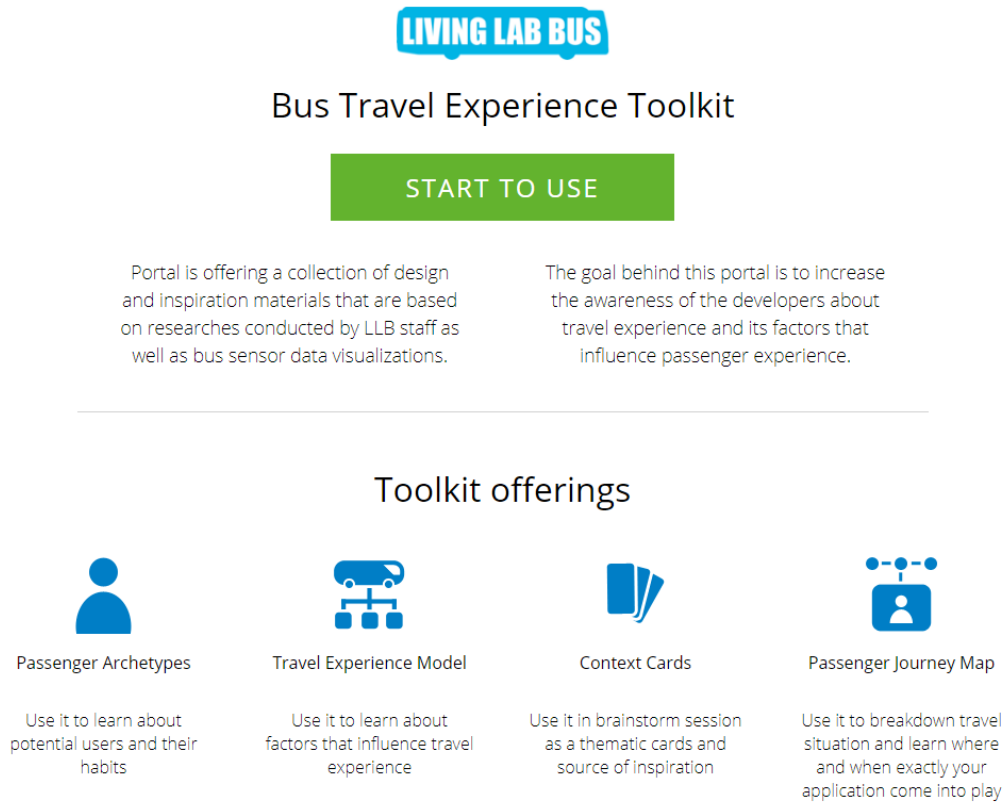



***Figure 8.9**. Introduction page is now more interactive and streamlined.*

**Production build and delivery**

Upon completing revision, prototype was moved to a production build, making it available for the Living Lab Bus to integrate within its structure in the end of January 2019.

Until integration started, prototype has been deployed on a temporal hosting by using GitHub Pages [30], a hosting for static websites provided by GitHub version management system.

# 9. DISCUSSION AND CONCLUSION

This chapter provides summary of the thesis work, presenting major findings, answers to research questions and potential future work on a topic.

## 9.1. Summary of Findings

The first and the second research questions were focused on discovery of certain properties of the Bus Travel Experience Toolkit and sensor data visualizations and their usage. These properties were be taken into consideration in order to help developers to use the Toolkit and the visualizations in their tasks. For that purpose, first developer study was conducted to discover developers' expectations for them. The results of this study that involved ten software developers evaluating two different usage scenarios were fairly fruitful. This study revealed several properties that needed to be considered when developing inspiration tools and/or improving the Toolkit: *importance of a proper terminology*, *provision of necessary research data behind Toolkit creation* and *suitable and understandable format of the tools*. These items served as a full answer to the **RQ1**.

In case of sensor data visualizations, it was discovered that it is best to provide *basic visualizations* (maps, charts, etc.) and *raw parameter values* instead of trying to present pre-processed suggestions based on the gathered sensor data to the developers. It served as a partial answer to **RQ2.** Reason behind partial nature of the answer is the fact that sensor data visualizations are very context -specific and this question was focused on practical application of the knowledge gained from the first developer study.

Thus, by designing and implementing first major version of the web portal prototype it was possible to establish the vision and structure to the future Toolkit portal. This prototype integrated all the necessary additions and changes to the Toolkit format, visualizations and terminology and sensor data visualizations. While Journey Map, Travel Experience Model and Context Cards received almost no changes to their format, Personas were supplemented with plenty of additions to ensure its interconnectivity with the rest of the Toolkit via direct links to semantically related tools. Sensor data visualizations were introduced as a list of sensor parameter values and geographical map, all updated in the real-time. This prototype in a form of a Single-

Page Application was a partial answer to **RQ3** as it required additional testing with software developers to finally confirm it.

Summative usability tests revealed correctness of established vision for both Toolkit and visualizations. Most of the concerns were cosmetic and none of them were severe enough to consider major changes to the prototype structure, Toolkit or sensor data visualizations. The prototype was reworked and improved visually and structurally based on the feedback from the developers. As a result, a production build of the prototype was created and deployed online via GitHub Pages hosting. The prototype served as a final answer to **RQ2** as visualizations took their final form of the mentioned list of parameter values with a map. It also answered **RQ3** as tested and improved prototype now includes entire Toolkit and visualizations that are all connected with each other.

## 9.2. Discussion

A great deal of inspiration-related works explore ways of facilitation of the ideation processes and decreasing mental workload. Software development requires a lot of intellectual effort and thus, deliverance of the context-specific tools for ideation cannot be emphasised enough. This thesis tries to deliver such context and provide a clear introduction to the inspiration materials related to bus transportation. Its approach to exploration through design allowed to gain a valuable practical knowledge regarding developer experience and inspiration.

Scenario evaluation sessions revealed some correlation with the Fagerholm's DevEx framework [23]. Quite a lot of developers mentioned the importance of having some problem to solve as their major drive. This need for contribution as well as feel of mastery and competence perfectly matches conative and affective dimensions of said framework.

Developers' strive for utilizing new tools and exploring new solutions can also lead to some unexpected outcomes. In case of this thesis work, developer wanted to see more technical documentation within the toolkit, considering it as a more of an "advertisement" for an Living Lab Bus' API rather than seeing actual value in it. This fact hints toward fact that there is a necessity of establishing a clear and strict vision of the tool.

In addition to that, sensor data visualization-related findings also elaborate on developers' need for control over own decision-making as they requested to give them basic maps and other basic instruments so they could form their own opinions.

Terminology concerns pretty much indicate the importance of speaking on the same language between design and software engineering fields which is not really raised by related works. Communication issues is a primary concern for many software projects [22]. Therefore, providing necessary communication and visualization tools becomes a problem of great significance. This issue was also noticeable during the study as some developers simply undervalued the Toolkit since there was a definite lack of research data and familiar terminology.

## 9.3. Limitations

This thesis work had a number of limitation regarding procedure of the first developer study and prototype implementation phase.

Timing of recruitment for scenario evaluation session was not perfect. Most of the study was conducted in the beginning of the summer season of 2018 and it resulted in a smaller number of potential participants than anticipated. Because of that, the study took more time than initially estimated. Other occurred obstacle was the actual introduction to the session materials. Participant were not exactly familiar with the scenario evaluation technique and thus, the purpose of the study and its conduct was seemingly vague for them.

As for the technical side of the thesis work, the major intent during the prototype implementation phase was to ensure proper development of the prototype as if it was a real website. That approach was motivated by desire to ensure prototype feasibility. While the overall structure of the prototype was fairly feasible, sensor data visualizations became a major issue. General lack of easily available backend infrastructure and expertise made the pool of possible visualizations quite limited. All of the content and real-time data was processed and rendered in the browser and thus, application performance was a serious concern. A proper backend support would have helped to avoid a great number of performance issues. It also could have allowed to produce real-time charts and other visual formats for each presented sensor parameter. In addition, historical data from Blob API could also have been added and pre-processed for much richer and more coherent visualizations.

Futhermore, another round of usability tests would have helped to finalize the prototype after second major iteration.

## 9.4. Future work

This thesis work left some openings for a potential future work.

For example, there is a possibility to expand the potential of sensor data visualizations in the context of inspiration and ideation. In case of bus sensor data, it is possible to create some sensor data patterns based on seasonal, daily, event-based passenger and bus traffic statistic. These can be used to develop inspiration and informercial materials for a specific urban areas that would help developers to understand its specifics.

Other opportunity can be related to creating some sort of template based on implemented portal and adapt it for other cities or even countries and data that can be collected there. Additionally, developer experience insight can further be explored within Fagerholm's framework, adding to existing data sample.

Lastly, there is a potential in formulating a proper guidelines for creation of similar ideation tools for software developers and expand it on various areas outside bus transportation, but also aviation, tram transportation and other modes of traveling.

## 9.5. Conclusion

This thesis presents various insights in a form of interactive web prototype of a bus Travel Experience Toolkit supplemented with bus sensor data visualizations. Thesis explored the ways of incorporating those items across three different topics of ideation, data visualization and developer experience. Ideation was a cornerstone of the theoretical basis of the research and most of the efforts were focused on exploring properties and artefacts of developer's ideation process and perception of the Toolkit.

As a result of discoveries, developers specified a set of certain expectations that they wanted to be considered when developing and enhancing inspiration materials within Toolkit: improve familiarity of the terminology and formats of each of the tools and provide enough research data to back the tools. As for data visualizations, developers expressed their desire to see more of a basic data visualizations to use them as a building blocks for their own decision making.

Additionally, developers shared their stories and experienced that can be break down into thematic insights that correspond with DevEx framework's dimensions, potentially contributing to them in the future.

In conclusion, despite content-heavy prototype, this is still an early step in providing highly contextual and holistic ideation tools for developers for a such specific urban infrastructure. In the future, one can hope that designers and researches will spend more efforts and time on delivering publicly available design and inspiration tools for various contexts, even those outside public bus transpiration.

# REFERENCES


[1] “Interaction Design Foundation - What are User Scenarios?” 2019. Available at: https://www.interaction-design.org/literature/topics/user-scenarios

[2] 512 Paths to the White House - Interactive Feature - NYTimes.com, 2019. Available at: http://archive.nytimes.com/www.nytimes.com/interactive/2012/11/02/us/politics/paths-to-the-white-house.html

[3] Across U.S. Companies, Tax Rates Vary Greatly- Interactive Feature - NYTimes.com, 2019. Available at: https://archive.nytimes.com/www.nytimes.com/interactive/2013/05/25/sunday-review/corporate-taxes.html

[4] Alfayez R., Behnamghader P., Srisopha K. & Barry Boehm B. 2018. An exploratory study on the influence of developers in technical debt. In Proceedings of the 2018 International Conference on Technical Debt (TechDebt '18). ACM, New York, NY, USA, 1-10. DOI: https://doi.org/10.1145/3194164.3194165

[5] Arrasvuori J., Boberg M. & Korhonen H. 2010. Understanding playfulness: An overview of the revised playful experience (PLEX) framework. Proceedings of the 7th International Conference on Design and Emotion.

[6] ArtStation, 2019. Available at: https://www.artstation.com/

[7] Audenhove V. & et al. The Future of Urban Mobility 2.0: Imperatives to Shape Extended Mobility Ecosystems of Tomorrow. Arthur D. Little, (2014).

[8] Behance, 2019. Available at: https://www.behance.net/

[9] Carreira R., Patrício L., Jorge R. N., Magee C. & Hommes Q. V. E. 2013. Towards a holistic approach to the travel experience: a qualitative study of bus transportation. Transport Policy 25, 233-243.

[10] Chau D.H., Kittur, A., Hong, J. & Faloutsos, C. 2011. Apolo: Interactive large graph sensemaking by combining machine learning and visualization. Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining. 739-742. 10.1145/2020408.2020524.

[11] Chen C., Hrdle W. & Unwin A. 2008. Handbook of Data Visualization (Springer Handbooks of Computational Statistics) (1 ed.). TELOS, Santa Clara, CA, USA.

[12] Cheng, P.J. & Ellen D. 2011. What you see is what you design: Exploring the influence of inspiration images in designers' ideation. Proceedings of the

DESIRE'11 Conference on Creativity and Innovation in Design. 10.1145/2079216.2079224.

[13] Coatta T. & Vitrium Systems. 2008. File Systems and Storage Vol. 5 No. 6. Available at: https://queue-acm-org.libproxy.tuni.fi/detail.cfm?id=1388789

[14] Collect UI - Daily inspiration collected from daily ui archive and beyond, 2019. Available at: https://collectui.com/

[15] Cooper A. 1999. The Inmates Are Running the Asylum. 53. 17. 10.1007/978-3-322-99786-9_1.

[16] Counsell S., Swift S., Tucker A. & Mendes E. 2006. Object-oriented cohesion subjectivity amongst experienced and novice developers: an empirical study. SIGSOFT Softw. Eng. Notes 31, 5 (September 2006), 1-10. DOI=http://dx.doi.org/10.1145/1163514.1163530

[17] Developer Portal - Living Lab Bus, 2019. Available at: https://llb.sis.uta.fi/portal/

[18] DeviantArt - Discover The Largest Online Art Gallery and Community, 2019. Available at: https://www.deviantart.com/

[19] Dong T. & Khandwala K. 2019. The Impact of "Cosmetic" Changes on the Usability of Error Messages. In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (CHI EA '19). ACM, New York, NY, USA, Paper LBW0273, 6 pages. DOI: https://doi-org.libproxy.tuni.fi/10.1145/3290607.3312978

[20] Donghwy A. & Nara Y. 2017. The inspirational power of arts on creativity. Journal of Business Research. 85. 10.1016/j.jbusres.2017.10.025.

[21] Dribble - Discover the World's Top Designers & Creative Professionals, 2019. Available at: https://dribbble.com/

[22] Errka V. 2013.Tietojärjestelmien hankinnan tila Suomessa 2013. Available at: http://URN.fi/URN:NBN:fi:tty-201311151438

[23] Fagerholm F. & Münch J. 2012. Developer experience: concept and definition. In Proceedings of the International Conference on Software and System Process (ICSSP '12). IEEE Press, Piscataway, NJ, USA, 73-77.

[24] Faste H., Rachmel N., Essary R. & Sheehan E. 2013. Brainstorm, Chainstorm, Cheatstorm, Tweetstorm: new ideation strategies for distributed HCI design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13). ACM, New York, NY, USA, 1343-1352. DOI: https://doi.org/10.1145/2470654.2466177

[25] Fontão A., Bonifácio B., Santos R. & Neto A. (2018). Mobile Application Development Training in Mobile Software Ecosystem: Investigating the Developer eXperience. 10.1145/3275245.3275262.

[26] Foth M. & Ronald Schroeter R. 2010. Enhancing the experience of public transport users with urban screens and mobile applications. In Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments (MindTrek '10). ACM, New York, NY, USA, 33-40. DOI=http://dx.doi.org/10.1145/1930488.1930496

[27] Fugiglando U., Santi P., Milardo S., Abida K. & Ratti C. 2017. Characterizing the "Driver DNA" Through CAN Bus Data Analysis. In Proceedings of the 2nd ACM International Workshop on Smart, Autonomous, and Connected Vehicular Systems and Services (CarSys '17). ACM, New York, NY, USA, 37-41. DOI: https://doi.org/10.1145/3131944.3133939

[28] Get Started | Geocoding API | Google Developers, 2019. Avaialble at: https://developers.google.com/maps/documentation/geocoding/start

[29] Girotto V., Walker E. & Burleson W.. 2017. Scalable Crowd Ideation Support through Data Visualization, Mining, and Structured Workflows. 183-186. 10.1145/3022198.3026349.

[30] GitHub Pages, 2019. Available at: https://pages.github.com/

[31] Golembewski M. & and Selby M. 2010. Ideation decks: a card-based design ideation tool. In Proceedings of the 8th ACM Conference on Designing Interactive Systems (DIS '10). ACM, New York, NY, USA, 89-92. DOI=http://dx.doi.org/10.1145/1858171.1858189

[32] Graziotin D., Fagerholm F., Wang X. & Abrahamsson P. 2017. On the Unhappiness of Software Developers. In Proceedings of the 21st International Conference on Evaluation and Assessment in Software Engineering (EASE'17). ACM, New York, NY, USA, 324-333. DOI: https://doi.org/10.1145/3084226.3084242

[33] Graziotin D., Fagerholm F., Wang X. & Abrahamsson P. 2017. Unhappy developers: bad for themselves, bad for process, and bad for software product. In Proceedings of the 39th International Conference on Software Engineering Companion (ICSE-C '17). IEEE Press, Piscataway, NJ, USA, 362-364. DOI: https://doi.org/10.1109/ICSE-C.2017.104

[34] HalfBakery, 2019. Available at: https://www.halfbakery.com/

[35] Helsingin seudun liikenne, 2019. Available at: https://www.hsl.fi/

[36] Herring S.R., Chang C.C., Krantzler J. & Bailey B.P. 2009. Getting inspired!: understanding how and why examples are used in creative design practice. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09). ACM, New York, NY, USA, 87-96. DOI: https://doi.org/10.1145/1518701.1518717

[37] Hildén E., Ojala J. & Väänänen K. 2017. Development of context cards: a bus-specific ideation tool for co-design workshops. In Proceedings of the 21st International Academic Mindtrek Conference (AcademicMindtrek '17). ACM, New York, NY, USA, 137-146. DOI: https://doi.org/10.1145/3131085.3131092

[38] Hildén E., Ojala J. & Väänänen K.. 2016. User Needs and Expectations for Future Traveling Services in Buses. In Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16). ACM, New York, NY, USA, Article 98, 6 pages. DOI: https://doi.org/10.1145/2971485.2996733

[39] Hildén E., Väänänen K. & Chistov P. 2018. Travel Experience Toolkit: Bus-Specific Tools for Digital Service Design. In Proceedings of the 17th International Conference on Mobile and Ubiquitous Multimedia (MUM 2018), Slim Abdennadher and Florian Alt (Eds.). ACM, New York, NY, USA, 193-197. DOI: https://doi.org/10.1145/3282894.3282916

[40] Hildén E., Väänänen K. & Syrman S. 2018. Modeling Bus Travel Experience to Guide the Design of Digital Services for the Bus Context. In Proceedings of the 22nd International Academic Mindtrek Conference (Mindtrek '18). ACM, New York, NY, USA, 143-152. DOI: https://doi.org/10.1145/3275116.3275120

[41] Inie N. & Dalsgaard P. 2017. A Typology of Design Ideas. 393-406. 10.1145/3059454.3059464.

[42] ISO (2016). ISO/IEC 25022:2016. Systems and software engineering. Systems and software quality requirements and evaluation (SQuaRE). Measurement of quality in use. Available at: https://www.iso.org/obp/ui/#iso:std:iso-iec:25022:ed-1:v1:en

[43] Kerne A., Webb A., Smith S., Linder R., Lupfer N., Qu Y., Moeller J. & Damaraju S.. 2014. Using Metrics of Curation to Evaluate Information-Based Ideation. ACM Trans. Comput.-Hum. Interact. 21, 3, Article 14 (June 2014), 48 pages. DOI=http://dx.doi.org/10.1145/2591677

[44] Kickstarter, 2019. Available at: https://www.kickstarter.com/

[45] Lee B., Srivastava S., Kumar R., Brafman R. & Klemmer S. 2010. Designing with interactive example galleries. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10). ACM, New York, NY, USA, 2257-2266. DOI: https://doi.org/10.1145/1753326.1753667

[46] Lewis C. H. 1982. Using the "Thinking Aloud" Method In Cognitive Interface Design (Technical report). IBM. RC-9265.

[47] Living Lab Bus – Open innovation and test platform, 2019. Available at: http://livinglabbus.fi

[48] Lucero A. & Arrasvuori J. 2010. PLEX Cards: a source of inspiration when designing for playfulness. In Proceedings of the 3rd International Conference on Fun and Games (Fun and Games '10). ACM, New York, NY, USA, 28-37. DOI=http://dx.doi.org/10.1145/1823818.1823821

[49] Lundqvist C., Klinkhammer D., Halskov K., Feyer S.P., Olesen J.F., Inie N., Reiterer H. & Dalsgaard P. 2018. Physical, digital, and hybrid setups supporting card-based collaborative design ideation. In Proceedings of the 10th Nordic Conference on Human-Computer Interaction (NordiCHI '18). ACM, New York, NY, USA, 260-272. DOI: https://doi.org/10.1145/3240167.3240177

[50] Lyon, G. & Urry, J. 2015. Travel time use in the information age. Transportation Research Part A: Policy and Practice, 39 (2-3), 257-276.

[51] Mackeprang M., Strama, J, Schneider G., Kuhnz P. & Benjamin J. & Müller-Birn C. 2018. Kaleidoscope: An RDF-based Exploratory Data Analysis Tool for Ideation Outcomes. 75-77. 10.1145/3266037.3266106.

[52] MeasuringU: 10 Things To Know About Completion Rates, 2011. Available at: https://measuringu.com/completion-rates/

[53] Nebeling M., Christoph Zimmerli C. & Norrie M.. 2013. Informing the design of new mobile development methods and tools. In CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13). ACM, New York, NY, USA, 283-288. DOI: https://doi-org.libproxy.tuni.fi/10.1145/2468356.2468407

[54] Node.js. 2019. Available at: https://nodejs.org/

[55] npm | the of the modern development community. 2019. Available at: https://www.npmjs.com/.

[56] Nyssen reittiopas, 2019. Available at: https://reittiopas.tampere.fi

[57] Oma Kokoelma - Living Lab Bus, 2019. Available at: https://llb.sis.uta.fi/

[58] Palviainen J., Kilamo T., Koskinen J., Lautamäki J., Tommi Mikkonen T. & Nieminen A.. 2015. Design framework enhancing developer experience in collaborative coding environment. In Proceedings of the 30th Annual ACM Symposium on Applied Computing (SAC '15). ACM, New York, NY, USA, 149-156. DOI: https://doi.org/10.1145/2695664.2695746

[59] Quirky, 2019. Available at: https://quirky.com/

[60] React – A JavaScript library for building user interfaces. 2019. Available at: https://reactjs.org/

[61] Redux · A Predictable State Container for JS Apps, 2019. Available at: https://redux.js.org/

[62] Rubin J. 1994. Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests (1st ed.). John Wiley & Sons, Inc., New York, NY, USA.

[63] Russell D., Stefik M., Pirolli P. & Card S. 1993. The cost structure of sense making.

[64] Siangliulue P., Arnold K.C., Gajos K.Z. & Dow S.D. 2015. Toward Collaborative Ideation at Scale: Leveraging Ideas from Others to Generate More Creative and Diverse Ideas. In Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15). ACM, New York, NY, USA, 937-945. DOI: https://doi.org/10.1145/2675133.2675239

[65] Siangliulue P., Chan J., Gajos K.Z. & Dow S.D. 2015. Providing Timely Examples Improves the Quantity and Quality of Generated Ideas. In Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition (C&C '15). ACM, New York, NY, USA, 83-92. DOI: https://doi.org/10.1145/2757226.2757230

[66] Simon H.A.. 1996. The Sciences of the Artificial (3rd Ed.). MIT Press, Cambridge, MA, USA.

[67] Smith G. (1998). Idea-Generation Techniques: A Formulary of Active Ingredients. Journal of Creative Behavior. 32. 10.1002/j.2162-6057.1998.tb00810.x.

[68] Somdulyawat C., Pongjitpak P., Phithakkitnukoon S., Veloso M. & Carlos B. 2015. A tool for exploratory visualization of bus mobility and ridership: a case study of Lisbon, Portugal. In Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers (UbiComp/ISWC'15 Adjunct). ACM, New York, NY, USA, 1117-1121. DOI: https://doi.org/10.1145/2800835.2800975

[69] Sosa R. & Dong A. 2013. The creative assessment of rich ideas. 328-331. 10.1145/2466627.2466663.

[70] Splechtna R., Diehl A., Elshehaly M., Delrieux C., Gračanin D. & Matković K. 2016. Bus Lines Explorer: Interactive Exploration of Public Transportation Data. In Proceedings of the 9th International Symposium on Visual Information Communication and Interaction(VINCI '16). ACM, New York, NY, USA, 30-34. DOI: https://doi.org/10.1145/2968220.2968238

[71] Tampereen seudun joukkoliikenne Nysse, 2019. Available at: https://joukkoliikenne.tampere.fi/

[72] TED: Ideas worth spreading, 2019. Available at: https://www.ted.com/#/

[73] The world's leading software development platform · GitHub, 2019. Available at: https://github.com/

[74] Thrash T. & Elliot A.J. 2003. Inspiration as a Psychological Construct. Journal of personality and social psychology. 84. 871-89. 10.1037/0022-3514.84.4.871.

[75] Trello, 2019. Available at: https://trello.com/en

[76] Viima - The Best Way to Collect & Develop Ideas, 2019. Available at: https://www.viima.com/

[77] Wartiovaara M., Lahti T.& Wincent J. 2018. The role of inspiration in entrepreneurship: Theory and the future research agenda. Journal of Business Research. 10.1016/j.jbusres.2018.11.035.

[78] Word Tree - Jason Davies, 2019. Available at: https://www.jasondavies.com/wordtree/

# APPENDIX A – "Inexperienced developer" scenario

## "Inexperienced developer" scenario

Jussi *is a junior software developer* at the recently formed *startup team* located in *Helsinki*. A new project opportunity is found it is heavily related to *bus transportation of Helsinki*.

While designers are working on a concepts and ideas, Jussi and other software developers' focus *is basic tasks and preparations* such as getting a bus location and other things that will definitely be used for a project. Jussi stumbles upon a couple of scientific papers that refer to *Living Lab Bus* project. He decides to take a closer look in case this LLB thingy may help their own. He discovers LLB portal and finds a link to the actual developer's portal. Jussi signs in with Gmail account (which was the fastest way to sign up alongside with using a Facebook account) and he enters the development environment.

The first thing he sees is an *introduction page* that shortly describes the tools and offerings this portal provides *(Figure 1)*. On a short presentation-like page with "slides" counter it is written about *API* developed by VTT Research Center that *could help with the technical dead-ends in the Jussi's project*, and about *design materials (personas, general guidelines, Context Cards and something called Bus Travel Experience model)* with some extensive *real-time data visualizations* to help the ideation process. There is also *a link to a LLB portal* on the end of this page with more info about project goals and *its collaborators and partners that Jussi's team can contact with*.

In the end of introduction part, there is *a tools selection between designer and developer (Figure 2)*. Jussi also noticed a *skip button* that skips entire introduction so Jussi could explore DevPortal freely. But he decided to click on "*Developer"* button that leads him to "For developers" section of the portal that contains API documentation and templates *(Figure 3)*. It also greets Jussi with a descriptive text that explains deeply about offered tools. He also noticed a *"Get started"* button under profile picture that enables entire introduction again.

Jussi decides to try these ones out by making a very small personal project, since there is not much going on at work. As soon as he started to think about personal project ideas he begins to *struggle with it.* He gets back to DevPortal and clicks on "*For designers*" *(Figure 4)* section that contains similar description of the tools - just like on developer's section. Suggested tools are: an interactive Bus Travel Experience model,

Context cards that explains various contexts of the bus travel, Personas and real-time sensory data visualizations. Text and button underneath offers to start with the model overview to get general idea.

Jussi clicks on this button and goes to the model that contains various contexts *(Figure 5)*. He them clicks on "*Physical context"* and entire model image zooms in expanding the "Physical context" part with some *descriptions about air quality and other things, related to physical attributes* of the bus travel experience *(Figure 6)*. By clicking on an "*Explore*" button alongside to"Air quality*"* title, Jussi goes to a new page with some *drawn person on it and a bunch of text (Figure 7)*. As written above the image, *this is air quality-related persona,* a collective image of user that is connected to the topic. Underneath persona *description and details (travel habits, need and many other) subsection*, there is another subsection titled as *"Related Context Cards"* and contains *"Making ecological values visible"* with some other ones.

Jussi also spots a text in "Real-time data" subsection *that describes some bus' air quality condition in the span of the last 5 days.* Text says*: "Air condition of the last 5 days was not great and it may not be comfortable for Olivia to use this bus until it will be fixed. It could be a good idea to design something that notifies her about it! She certainly doesn't like to travel in a smelly buses".* Turns out this data is taken from sensors in one of the busses in Helsinki in real time! There is also a button that *gets a new random fact* based on sensory data and related to the air condition.

Jussi is pleasantly *shocked* of how broad this system is and decides to work on that direction as suggested on the page. He decides to use API to create a map that shows trackable busses on the map with air quality indicator of each of them by using some color coding (red is bad, green is good). After a day or two of working on it he shows his app to his coworkers and designers and explains the purpose of the LLB platform and potential value of it for their project. On which they all agree and successfully pitch the idea of using LLB tools for their project to project's lead developers.

# APPENDIX B – “Limited designer” scenario

## “Limited designer” scenario #2

Heimo is recently graduated UX student. In order to expand his portfolio, he decides to develop some small-scale personal project related to the bus transportation of Helsinki. Heimo starts his ideation process with on-field observation of passengers and bus environment. After spending some time doing this, he formulates a goal of his project - to create an app that shows the occupancy of particular bus so passenger could avoid overcrowded lines or specific buses.

But at this moment he also realizes that there some obstacles on his way. He does not know how to validate and confirm his idea without conducting a massive research and spending too much time. In one of the days he notices a public display in one of the buses that advertises something called *Living Lab Bus* (LLB) project. Back at home, he googles it and it leads to a LLB main page. After exploring the website for sometime to get an idea what is this LLB is about, he finds a *DevPortal* link.

He is greeted with some *text popup* that introduces DevPortal offerings to him, including *API and design materials to support ideation (Figure 1)*. Apparently these materials are based on real researches and that is what get Heimo curious. Considering API for much later use, Heimo finds a button on the popup that leads to design tools. On design tools page he sees another popup that suggests a selection between 3 types of design materials to support different ideation levels *(Figure 2)*: *Context Cards* that contain general design concepts, *Travel Experience model* that demonstrates the actual contexts within the travel experience and *Personas* that are collective images of potential users with specific needs, behaviour and preferences. It also mentions that *each of the tools is supplemented with real-time data extracts* that also enriches the materials with detailed visualizations.

Since Heimo is already knows what kind of idea he has - *he just needs to confirm that is works on paper*. He clicks on Personas button, it leads to a set of selectors/tags that can help to find desired persona instead of manually looking for them in the list *(Figure 3)*. He selects following tags - “*occupancy*” and “*noise level*” - and he received a list of *related personas*. In that case it is only one - *Isac Isolation*. Heimo selects this persona and it leads him to an extended view of the persona *(Figure 4)*. Alongside with basic information and related contexts, there are suggestions for a potential apps ideas that could be useful for Isac. Here are as well some real-time data example of bus occupancy for a set of buses that demonstrates which of the buses will likely be chosen by Isac to travel. There are also link-like buttons that lead to a Travel Experience model and Isac-related contexts.

But Heimo already got what he needs - a basic confirmation that his idea could work and is relevant to some people. On that note, he goes to the developer's tools section of the portal and starts to work with API and other tools, eventually completing his project.

# APPENDIX C – Interview questions for scenario evaluation

## Interview questions

Scenario

1. What do you think of this scenario? Did it make sense for you? Did it sound realistic enough? Were design materials introduced properly? Did sensory data make sense in this context?
2. Best part of scenario? Like one specific element, situation or event that you liked most / you find the most appealing / interesting / motivating? And the worst one? Why best/ why worst?
3. What kind of things you are missing in this story? Is there something you may think of to improve in LLB tools usage or LLB offerings or the way you may navigate through the portal?

Design material expansion

4. What kind of real-time data/sensory data can be useful for this case/for you personally?
5. How these design materials can be expanded or supplemented in general? Aside from what was shown and explained.

Personal preferences

6. What are the sources of inspiration for your own projects?
7. Do you use some kind of design guidelines or inspiration materials for your projects?

# APPENDIX D – Background questionnaire for scenario evaluation

## Background questionnaire

**Age _____**

**Gender**

[ ] male

[ ] female

[ ] other

[ ] do not want to specify

**Occupancy**

[ ] software developer / student-developer

[ ] designer / student-designer

[ ] other _____

**Did you previously participated in startups?**

[ ] yes

*(optional) if yes, which one?* _____

[ ] no

**Did you previously participated in open-source projects?**

[ ] yes

*(optional) if yes, which one?* _____

[ ] no

**Are you familiar with Living Lab Bus platform and/or its Developer Portal?**

[ ] yes

*if yes, how did you learn about it?*

_____

[ ] I heard of it, but never used it or looked at it

*if you heard of it, where exactly?*

_____

[ ] no

# APPENDIX E - Background questionnaire for scenario evaluation

## Post-reading questionnaire

*Please rate each statement according to your impressions from the scenario.*

| | Unconvincing | | | | Realistic |
|---|---|---|---|---|---|
| This scenario is... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Worthless | | | | Beneficial |
| Design materials in this scenario seem... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Worthless | | | | Beneficial |
| Sensory data extract in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Tricky | | | | Clear |
| Navigation proposed in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Complicated | | | | Simple |
| Sensory data presentation and description in Developer Portal seem... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Nonsensical | | | | Logical |
| Order of design materials in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |

# APPENDIX F – Post-reading questionnaire for scenario evaluation

## Post-reading questionnaire

*Please rate each statement according to your impressions from the scenario.*

| | | | | | |
|---|---|---|---|---|---|
| | Unconvincing | | | | Realistic |
| This scenario is... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Worthless | | | | Beneficial |
| Design materials in this scenario seem... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Worthless | | | | Beneficial |
| Sensory data extract in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Tricky | | | | Clear |
| Navigation proposed in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Complicated | | | | Simple |
| Sensory data presentation and description in Developer Portal seem... | [ ] | [ ] | [ ] | [ ] | [ ] |
| | Nonsensical | | | | Logical |

| | | | | | |
|---|---|---|---|---|---|
| Order of design materials in this scenario seems... | [ ] | [ ] | [ ] | [ ] | [ ] |

# APPENDIX G – Consent form for scenario evaluation

## Consent form

### Description

This design study session is a part of Living Lab Bus project. The primary focus of Living Lab Bus is a development of an open platform for developers to design and implement their own solutions in the field of the public bus transportation. By participating in this session, you will help us to discover the potential and problems in provided scenarios that describe the usage of design materials combined with sensory data retrieved directly from bus' sensors. These materials and sensory data are meant to support ideation process of the developer and goal of the study is to find out if proposed format is feasible and usable.

### Procedure

During the session you will read a two different scenarios that explain a possible structure of Developer Platform and methods of utilization of design materials and sensory data. After each scenario, you will be asked to fill a post-reading questionnaire and a short interview will be conducted. Interview part will be audio recorded. After this stage, you will receive a current version of design materials so you can also check them out and form an opinion on them. After that there will a final short interview.

### Duration

Approximate duration of the procedure is 1 hour.

### Participant's rights, risks and benefits

Any of the personal data or voice recording will not be revealed publicly and will be handled anonymously within Living Lab Bus project and this design study in particular. Participation in this study is voluntary. After the session, you will be rewarded with a Finnkino movie ticket.

### Contact information

If you have any questions, concerns or complaints about procedure or overall study, contact *Pavel Chistov* (+358403705193 / +358504478425 / pavel.chistov@tut.fi)

**SIGNATURE AND PRINTED NAME** _____

**DATE AND PLACE** _____

# APPENDIX H – Consent form for usability tests

## Consent form

### Description

This testing session is a part of Living Lab Bus (LLB) project. The primary focus of Living Lab Bus is a development of an open platform for developers to design and implement their own solutions in the field of the public bus transportation. By participating in this session, you will help us to refine a particular portal that contains *Bus Travel Experience Toolkit* (Passenger Personas, Travel Experience model, Context Cars and Passenger Journey Map) created for software developers and are based on passenger researches conducted by LLB. Additionally you will get familiar with bus sensor data visualizations that are also part for the portal.

### Procedure

During the session you will be given a task to explore the portal and its content. Then, you will be asked to fill basic questionnaire and an interview will be conducted as a final part. Your voice and computer screen will be recorded during task performance. Following interview part will be audio recorded as well.

### Duration

Approximate duration of the procedure is 1 hour.

### Participant's rights, risks and benefits

Any of the personal data or voice recording will not be revealed publicly and will be handled anonymously within Living Lab Bus project and this design study in particular. Participation in this study is voluntary. After the session, you will be rewarded with a Finnkino movie ticket.

### Contact information

If you have any questions, concerns or complaints about procedure or overall study, contact *Pavel Chistov* (+358403705193 / +358504478425 / pavel.chistov@tut.fi)

**SIGNATURE AND PRINTED NAME** _____

**DATE AND PLACE** _____

# APPENDIX I – Background questionnaire for usability tests

## Background questionnaire

**Age** _____

**Gender**

[ ] male

[ ] female

[ ] other

[ ] prefer not to specify

**Occupancy**

[ ] software developer / student-developer

[ ] designer / student-designer

[ ] other _____

**Are you familiar with Living Lab Bus platform and its offerings?**

[ ] yes

*if yes, how did you learn about it?*

_____

[ ] I heard of it, but never used it or looked at it

*if you heard of it, where exactly?*

_____

[ ] no

# APPENDIX J – Tasks for usability tests

## Tasks

You are an experienced software developer thinking of creating some bus related application. You stumbled upon a Living Lab Bus portal that contains some research-based design materials related to bus transportation. While exploring the portal and its contents, you need to:

1. **Get familiar with the portal, its purpose and what kind of design tools it offers. Find out how these tools were created and based on what researches.**

2. You start to brainstorm to specify the context and value of your future application. **Find a suitable tool offered by the portal and get familiar with its content.**

3. You need to think of potential users (passengers) - their habits, needs and preferences. **Find a suitable tool offered by the portal and get familiar with its content.**

4. You need to know when and where exactly your application is used. For example, you can break down a typical bus travel situation and find a point where passengers would use your application. **Find a tool for that purpose in the portal and get familiar with its content.**

5. It is important to know what factors could influence the bus travel for a passenger and therefore - you application usage. You need to see a bigger picture. **Find a suitable tool for that in the portal and get familiar with its content.**

After some thinking, you can start thinking about implementation. You need to learn about bus technical details and bus sensor data (location, speed and other parameters) that you could use or visualize in application. **Find related information and examples on the portal.**

# APPENDIX K – Post-testing questionnaire for usability tests

## Post-testing questionnaire

*Please rate each statement according to your impressions from the portal (1 = strongly disagree, 5= strongly agree)*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **I feel …** | | | | | |
| … that I learned something new from materials and visualizations | | | | | |
| … that I got some valuable insight about passengers and bus context | | | | | |
| … that I can use this information in case I was developing a bus related application | | | | | |
| **I find content and format of …** | | | | | |
| … passenger archetypes (personas) useful and easy to understand | | | | | |
| … travel experience model useful and easy to understand | | | | | |
| … journey map useful and easy to understand | | | | | |
| … context cards easy useful and easy to understand | | | | | |
| **I think sensor data visualizations …** | | | | | |
| … are visually pleasant | | | | | |
| … are easy to understand | | | | | |
| … give enough information about bus environment | | | | | |
| … contribute to the knowledge about bus contexts and passengers | | | | | |
| … have a logical connection with design materials / tools / toolkit | | | | | |
| … could use more basic visualizations (charts, graphs, maps, ...) | | | | | |
| **I think navigation …** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| … logical | | | | | |
| … easy to use | | | | | |
| … looks and feels familiar | | | | | |
| **I think layout of the portal …** | | | | | |
| … is clean | | | | | |
| … is well structured | | | | | |
| … reminds me of similar websites | | | | | |
| **I think colors of the portal …** | | | | | |
| … are botched | | | | | |
| … are appealing | | | | | |
| **I find visual design and style of the portal ...** | | | | | |
| … consistent | | | | | |
| … appealing | | | | | |
| … up-to-date | | | | | |
| **I think terminology and naming convention …** | | | | | |
| … are easy to understand | | | | | |
| … are appropriate | | | | | |
| … have a logic behind them | | | | | |

# APPENDIX L – Interview questions for usability tests

## Interview questions

1. How do you feel about the portal? Is it easy to use? Is it structured well?
2. How do you find its aesthetics and layout? Does it looks familiar or completely alien to you?
3. What do you think of toolkit presentation? Did you get the idea of it? What do you like the most? Was it easy to understand? Do you find content useful and worth exploring?
4. Do you feel that you learned something while navigating through the portal?
5. Would you return to the portal and use it again or do you see it as a one-time use thing?
6. From 1 to 10, how would you rate: aesthetics, usability, usefulness, ease of use?